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TEXT-BOOKS OF SCIENCE

ADAPTED FOR THE USE OF

ARTISANS AND STUDENTS IN PUBLIC AND SCIENCE SCHOOLS

PHOTOGRAPHY

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A TREATISE ON

PHOTOGRAPHY

BY

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PREFACE.

THE AIM of this book is chiefly to give a rational explanation of some of the different phenomena to be met with in Photography; and with this to give sufficient practical instruction to enable the student to produce a landscape picture which shall be technically good, and at the same time to be of use to him if he make photography an aid to research.

In regard to the theories which the author has enunciated, it is believed that experimental evidence completely justifies their adoption. Though rapid advance has been made of late years in rule of thumb photography, yet the progress has been but slow in the science of it since the days when Herschel, Draper, Becquerel, and others instituted their researches; and if this book can be but the means of enlisting a few earnest workers in investigating some of the remaining problems which still require solution, another aim of the author will be accomplished.

In a measure supplemental to this treatise, as far

as practical work is concerned, is 'Instruction in Photography,' by the same author. At one time it was hoped that the two might be combined, but after much consideration it appeared impossible to compress the necessary matter into the pages to which each volume of this series is limited.

This will explain why some—what may be called commercial—applications of photography have not been noticed in the present work, as it was thought more advisable that the available space should rather be devoted to the more theoretical aspect of the subject.

The author has to record his thanks to Mr. Dallmeyer, and to Mr. H. P. Robinson, for the criticism they passed on the proof sheets of chapters xxix. and xxxi. respectively; and also to Mr. J. Traill Taylor for the permission to use copies of some of the diagrams of lenses in chapter xxix. which illustrated his article in the 'British Journal Photographic Almanac,' 1870.

Nor can the author omit to acknowledge the great obligation he is under to Mr. C. W. Merrifield, F.R.S., the editor of a part of this series, for the valuable help and advice which was so cordially given whilst this work was passing through the press.

SOUTH KENSINGTON MUSEUM:
January 1878.

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A TREATISE

ON

PHOTOGRAPHY.

CHAPTER I.

HISTORICAL SKETCH OF THE DISCOVERY AND PROGRESS OF PHOTOGRAPHY.

To the alchemists of the sixteenth century belongs the honour of having first noticed the change that took place in silver chloride (known to them as 'Luna cornua') by exposure to light, but they regarded the darkening as a species of transmutation of metals, and it remained for Scheele, the Swedish chemist, in 1777, to investigate the properties of this compound, though his researches led at the time to no practical end. Scheele found, when he exposed silver chloride to the action of light beneath water, that in the fluid was dissolved a substance which, on the application of silver nitrate, gave once more silver chloride, and that, after applying ammonia to the blackened body, an insoluble residue of metallic silver remained behind. These were the only facts elicited at the time, and a delay of more than half a century occurred before they were put to really good purpose. In 1801 Ritter, of Jena, repeated the experiments of Scheele, and discovered that the chloride darkened rapidly in those rays of the spectrum which lie beyond the extreme violet. To him also is due the announcement that the red

'7

rays have the property of undoing the work effected by the violet, though he attributed the effect to the wrong cause.

In 1802 Thomas Wedgwood read a paper before the Royal Institution, entitled 'An account of a Method of Copying Paintings on Glass [1] and of making Profiles by the agency of Light upon Nitrate of Silver.'

With these experiments of Wedgwood's Sir Humphry Davy was associated, and in their record we find it stated that muriate of silver was more readily acted upon by light than the nitrate, and that white leather used as a basis gave better images than paper. Images obtained by the solar microscope were impressed without any serious difficulty, but no means was discovered of rendering them anything but transitory when exposed to daylight. For Charles, a Frenchman, has been claimed the credit of employing at an earlier date the same method of obtaining black profiles by the action of light, but there seems to be no authentic proof extant that this claim should be allowed. Dr. Wollaston, in 1803, discovered that gum guaiacum, when exposed to the action of the blue rays of light, became changed in colour, and that on exposing those altered portions to the red rays, the original tint was restored.

In 1814 Photography was to receive a new votary in the person of Joseph Nicéphore de Niépce. Leaving the salts of silver, he devoted himself to the study of the action of light on resins. After several years of research, he at length completed the process known as heliography, which consisted in the production of a picture in bitumen on a polished metal plate. The discovery he made in regard to this resin was that, after insolation, it became insoluble in its ordinary solvents. An exposure of many hours in a camera obscura was necessary to produce the required effect; hence, as may be imagined, the views taken by this means

[1] A mistake often occurs in the reading of this sentence. Wedgwood did not make the copies on glass, but copied paintings which were drawn on glass.

were wanting in vigour, owing to the shifting direction of the sunlight, and, as we shall see later on in this work, from other causes, were of necessity deficient in delicate lights and shades. In 1827 Niépce came over to England, with the intention of drawing the attention of the Royal Society to his discovery, but his process being secret, his communication was not received, and he returned to France. In 1824 Daguerre, a French painter, began a series of experiments in the same direction, and in 1829 he and Niépce entered into a partnership, and presumably it was the knowledge of the latter's method of working which gave the former the idea of the daguerreotype. Niépce had employed silver plates covered with asphaltum, which, after exposure and application of the solvent, left the metal bare in parts. The image thus formed was brown; the shadows being represented by the metallic surface. In order to produce a proper effect, it was necessary that the parts covered by the bitumen should be whitened and the bare parts darkened. After various experiments, he applied iodine to the picture, subsequently removing the bitumen. It is to be presumed that Daguerre noticed the action that the light produced on those portions of the plate which had been converted into iodide. At any rate to Daguerre belongs the glory of the discovery that an image could be produced on a silvered plate which had been exposed to the vapour of iodine, though it was by fortuitous circumstances that he hit on the method of developing an invisible image.

In January 1839 the discovery of the daguerreotype process was first announced, and in August of the same year the details of production were given to the world, Daguerre and Niépce the younger (the successor of Nicéphore), obtaining a pension from the Government of France. Whilst Daguerre was working in France, we find that one of our own countrymen, Fox Talbot, had been experimenting in another direction. Bearing in mind the work of Scheele and Wedgwood, he devoted himself to the production of

drawings, &c., on silver chloride, and in January 1839 he read a paper before the Royal Society on 'Photogenic Drawings.' His method of procedure was somewhat as follows: Writing paper was coated with a solution of common salt, and after drying was brushed over with silver nitrate; by this means silver chloride was obtained, with a slight excess of the nitrate, in which condition it proved excessively sensitive to light. Various bodies, such as lace and ferns, were laid on this paper, and a reversed facsimile of them in black and white was produced, and he fixed the

FIG. 1.

FIG. 2.

impressions by solutions of bromides and chlorides. When such a reversed facsimile was placed over similarly-prepared paper, and the light allowed to act through it, the result was the formation of a facsimile, only this time not reversed in shades.

These two prints were respectively named the negative and the positive (fig. 1 and fig. 2.)

Comparing this process with the former, we see what an immense advantage Talbot's process had over the daguerreotype. With Talbot's any number of copies of a subject could be cheaply produced, whilst with the latter

one positive was the sole result, unless expensive electro-chemical means were resorted to.

The Rev. J. B. Reade was also an ardent experimentalist in this process, and to him is to be ascribed the discovery of the accelerating power of gallic acid, in the presence of silver nitrate, for the production of an image, and also for the *development* of the invisible image by the same agency.

From this discovery, together with that of Daguerre's, Fox Talbot reasoned out the calotype process, which he patented in 1841. By it an invisible image is formed on silver iodide on paper, and developed by gallic acid. In this process of Talbot's a negative image was formed, while by the first process the positive pictures were produced; and it should be remarked that the same method of producing silver prints obtains to the present day with scarcely any alteration.

Sir John Herschell had drawn attention to the possibility of producing photographic pictures on glass, and in 1843 had actually printed, in a camera obscura on silver chloride, deposited on such a plate, a picture of his 40-foot telescope. Niépce de St. Victor made a further great advance when he succeeded in holding the sensitive salts of silver on glass by using albumen as a vehicle, but to Le Gray must be accorded the credit of suggesting collodion as suitable for retaining them *in situ*. Scott Archer, with whom was associated Dr. Hugh Diamond, in 1851, however, introduced the collodion process in the practical form in which it exists to-day, and it may safely be said, that, with the exception of the daguerreotype process, no more important discovery in photography has been made.

In 1839 Mungo Ponton published the fact that potassium dichromate, when applied to paper and dried, altered in composition when exposed to the influence of light. This announcement caused much investigation into the subject, and it was subsequently discovered that not only was the chromate altered in composition, but that the sizing

of the paper was oxidised. Gelatine, gum, starch, albumen, were all found to become insoluble when exposed in contact with it; and Poitevin utilised this fact in the production of pictures in powdered carbon by a process analogous to that subsequently to be described in these pages. Swan, Johnson, Woodbury, and others, have more recently extended its application by the production of images formed in gelatine, coloured with pigments; whilst a still wider field has been opened by Albert, Edwardes, and others, in the production by mechanical means of prints in printers' ink from a gelatine image, founded on the fact that oxidised gelatine is incapable of absorbing water.

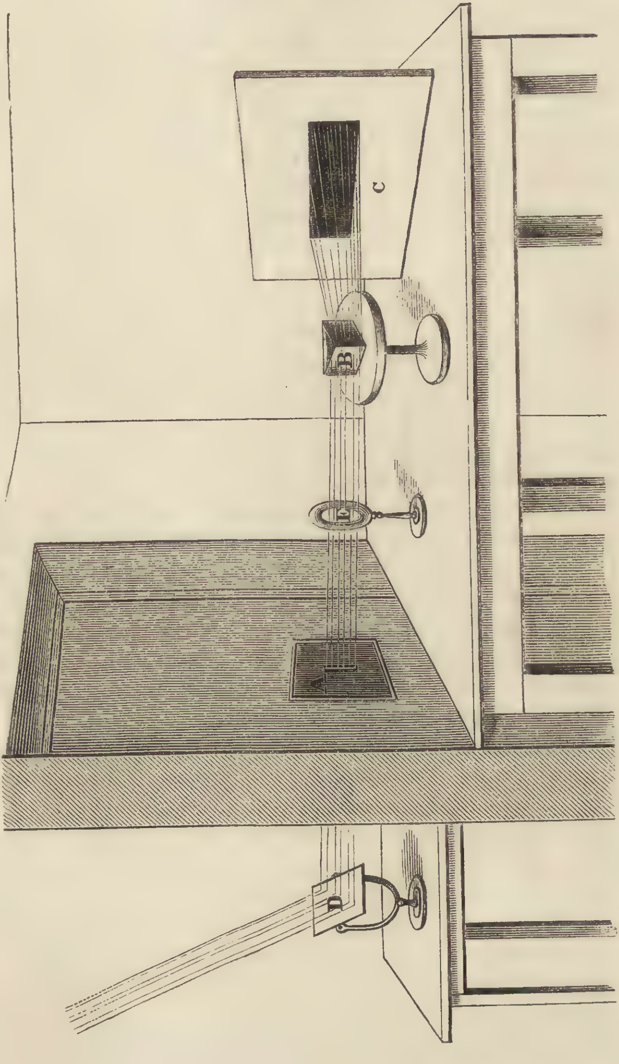
CHAPTER II.

EXPERIMENTS WITH LIGHT.

BEFORE entering into the theory of photography, it will be convenient to enter briefly into some of the phenomena of light; for it is with this form of energy that the photographer has to deal. It will be as well first to try one practical experiment with light, in order to clear up certain difficulties which may present themselves.

Darken a room of some 12 or 14 feet in length by means of shutters (light wooden frames covered with opaque paper will answer), and in one fix a small plate of glass, A, which has previously been covered with tinfoil, and on which, with a sharp knife, has been cut a straight line laying bare the glass; on a table place a glass prism, B, the centre of which is at the same height as that of the slit, and have a screen, covered with white paper, C, and a lens, E, of about 12 inches focus, ready at hand; outside the window arrange a mirror, D —an ordinary looking-glass will answer—in such a position as to reflect the sunlight on to the slit: interpose the lens, E,

FIG. 3.



about 6 inches from A, in such a manner as to cause the beam to fall upon the prism, B. The floating dust in the room will immediately show that the original beam of white light has been split up into a series of coloured rays, and a position for the screen may then be found which will cause the top and bottom edge of the spectrum (as this glorious band of colour is termed) to be sharply defined; and if the cut in the tinfoil be fine enough, a series of dark lines will traverse it vertically. With these, however, we have nothing to do at present. Now experiments, the results of which have formed the groundwork of mathematical reasoning on the theory of light, have conclusively proved that light *as* light is merely a sensation. Permeating all known space is assumed to be an imponderable and elastic fluid known as ether, and in it a luminous or heat source is able to generate a series of ripples or waves, flowing unbrokenly and continuously from it. What the prime form of these undulations may be we cannot tell. They may be, and most probably are, compounded of an almost infinite number of different undulations, when ordinary[1] white light is the impression given to the eye, and each of these series of undulations vary in length from crest to crest. Those of certain lengths are able to affect the nerves which line the retina of the eye; whilst some of these are able to affect other nerves lying in our bodies, producing the sensation of heat; others again, though incapable of producing the sensation of light or heat, exhibit themselves by their effect on certain compounds, causing chemical combination or decomposition. Of those waves whose impact on the eye produces the sensation of light the shortest is about 600 millionths of a millimetre, whilst the longest is about 350 millimetres. The former give the sensation of a violet colour, the latter of a brilliant red. Examining the spectrum thrown on the screen, the intermediate colours of blue, green, yellow, and orange are seen, and the wave-lengths producing their effects

[1] *i.e.* not polarised.

on the eye lie intermediate between the limits given above. There is uncertainty as to the lower limit to which the heat-producing rays are refracted, but probably to a length equal to that of the visible spectrum, whilst the range in length of the chemically active waves other than those situated in the visible portion of the spectrum, and which lie beyond the violet (being called the ultra-violet or fluorescent rays), is, if anything, still more uncertain. It will be evident on reflection that it must be accidental that, between certain limits, the waves should be capable of producing a sensation of light or of heat. The exact upper limit of the thermal spectrum is unknown, but from theory it must be co-terminous with the chemically active rays, as will be seen further on, the inferior limit of the capacity of any waves to produce decomposition is as yet unascertained. All those series of waves which effect decomposition in any compound are called *actinic* rays, and, as will be seen, the range of these vary for every ordinary photographic compound.

It may help us in a right comprehension of our subject if reference is made here to one quality of these undulations. The interstellar ether in which these waves ripple is assumed to permeate every body, solid, liquid, and gaseous; and it depends upon the disposition of the ultimate molecules of the body whether it is opaque or transparent to any of the visible or dark rays of light. It must be borne in mind that the molecules of every substance are presumably in a state of vibration, the extent and velocity of which depend partly upon the temperature, and partly upon the nature, of the substance, and that this must ever be so unless the purely theoretical condition of absolute cold be arrived at. Supposing, then, we have a glass, which with white light falling on it allows only the transmission of red light, and we look through it at the spectrum formed by white light, we should find that it cuts off the whole of the colours excepting the red, obliterating them more or less perfectly, that is, in technical language, it absorbs them. Now, according to all

ideas of the conservation of energy, this absorption must indicate the performance of some kind of work. It may be that it causes the already vibrating molecules of the glass to take up and swing in some complicated manner with those rays particularly absorbed, and thus to cause a rise in temperature in the body, so small indeed, perhaps, as to be indistinguishable, owing to the rapid cooling due to radiation; or it may be that work is performed in effecting chemical decomposition, for even glass is thus affected by light. The rays which simply pass through the glass produce no effect on it—their energy is unimpaired.

It should also be noted that where light is not entirely absorbed, but is only reduced in intensity, even then also work must be performed by it; for the intensity of any coloured or white light is dependent on the extent, or amplitude, as it is termed, of the wave or waves; and any diminution of the amplitude indicates that a portion of its available energy has been exhausted, and that therefore a transference of the portion so expended must have been made to the body through which it passed. This exchange or transference of energy is an important subject in all photographic matters; it explains many of the phenomena in photography which often present a great difficulty to the beginner or to the rule-of-thumb photographer, whilst it is all-important in the right understanding of the revelations which are made by the spectroscope.

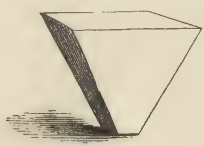
It may then be laid down as an unalterable law, that *where there is absorption of light* (*whether of dark or visible rays*) *by any body*, *work of some description must have been performed in that body.* An account of the valuable experimental research of Joule on the mechanical value of light is given at length in the 'Philosophic Magazine' for 1843, and is deserving of special study.

CHAPTER III.

THEORY OF SENSITIVE COMPOUNDS.

EVERY particle of matter may be considered to be made up of molecules, each molecule consisting of constituent atoms. Thus a particle (and when we say particle we mean to convey the idea of the smallest visible quantity of matter) of silver iodide is composed of molecules of a like definite composition, the components being—two atoms of iodine and two of silver, or multiples of these numbers. The physical aspect of matter often conveys to the mind an idea of a certain kind of arrangement in the molecules; as does the analysis of a compound, if not of the absolute arrangement of the atoms, at all events of the arrangements which they cannot take. Oxalic acid, for instance, we know is composed of carbon, hydrogen, and oxygen, having the formula $C_2 H_2 O_4$, or the exact equivalents of water, $H_2 O$, carbon monoxide $C O$, and carbon dioxide $C O_2$, yet the compound is totally different in its physical characters and chemical reactions from any of these. From this we can argue that the atoms of its molecules must be separated in such a manner that the oxygen molecules cannot seize upon the hydrogen to form water, or on carbon to form carbon monoxide or dioxide. When the atoms are so arranged as to be incapable of forming a molecule of a simpler type, they occupy a position of excessively stable equilibrium, and it would be necessary to expend a large amount of work to separate them. On the other hand, where the atoms of the molecule are so grouped that by rearrangement they may form perhaps more than one molecule, each of which may be

FIG. 4.



of less complex character, it often happens that all the atoms are in state of stable, though verging on indifferent, equilibrium. We may take as an illustration of this state of equilibrium the frustum of a pyramid standing base uppermost, on a narrow section parallel to the base. It is apparent that the work expended in order to cause the frustum to find a new position of more stable equilibrium (or, in other words, to fall on to one of its sides), may be made as small as we please by diminishing the area of the section on which it stands. Whilst falling, the body can do a certain amount of work, which will be quite independent of the amount of work expended to cause its fall. So with the atoms of a molecule which are in this state of almost indifferent equilibrium ; a very small amount of work need be expended in order to cause them to take up more stable positions ; but the kinetic energy they may possess whilst passing to this new state, need be no measure of the work performed upon them. A measurement of the work performed by their re-arrangement would principally tell what amount of work had been expended in some chemical process, in order to place them in that state bordering on indifferent equilibrium. It is *possible*, however, under certain circumstances, to compare two or more energies with one another, by comparing the effects they produce on such molecules. Extending our previous illustration, supposing we had a row of such frusta of pyramids, and that it was found that one pellet of a number (all being of equal weight) when striking one frustum with a certain velocity, was able to cause it to fall, and also that in every case the accuracy of aim was undoubted, and that in falling one frustum did not strike its neighbour ; then at any interval after the commencement of a bombardment the amount of work expended in projecting the pellets could be compared by simply counting the number of frusta which had fallen.

It is in a manner akin to this that the comparative values of the intensity of those rays which produce chemical

decomposition in sensitive compounds are found. The molecules of the compound answer to the frusta, and the pellets to the number or amplitude of the waves impinging on them. The method of estimating the number of molecules altered in composition, is by noting the colour or the attractive power on other matter which they possess. In our illustration we assumed that one frustum never interfered with another during its fall, and, so far as the compounds, which are photographically sensitive, are concerned, this is a correct assumption, for the alteration in one molecule does not cause an alteration in the neighbouring one. In other sensitive compounds this may not be the case. It is frequently the case that the rearrangement of the atoms of a molecule calls into play such a large amount of kinetic energy (it may be in the form of heat), that the neighbouring atoms are caused to rearrange themselves, and so on. In this case the destruction of the original form of the molecules may be so rapid, and the potential energy converted into kinetic may be so large, that we may have a compound which is an explosive. With these latter compounds the energy existing in a vibration is often sufficient to cause explosion. The vibration may be that of the longer waves produced in the medium we have already discussed, or may be those produced in the atmospheric or other gases. Thus, radiant heat may cause it, as also sound. It has been experimentally proved that many explosives are particularly sensitive to vibrations of a definite wave length; thus, the vibration to which nitro-glycerine is most sensitive is not the best with which to cause the explosion of gun-cotton. It has also been asserted that the atoms of the molecules of iodide of nitrogen can be caused to be dissociated by the atmospheric waves which are due to sound of a particular pitch.

In order to understand more readily how it is that the molecules of such bodies may be disturbed by waves of a certain length, it must be recollected that they are in a state of agitation. In solids the paths they describe are limited,

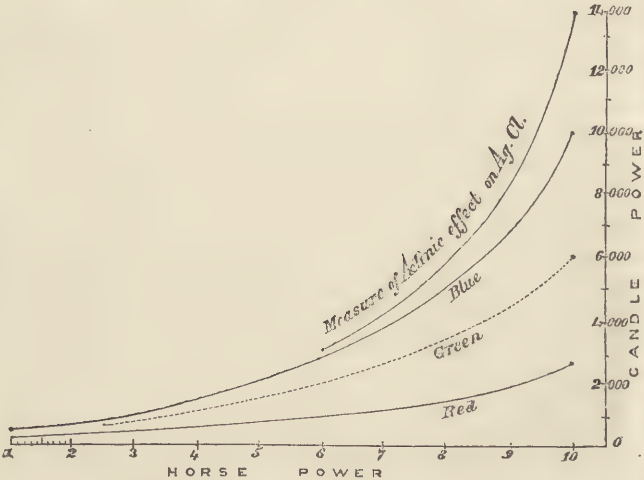
though the excursions they take will be the greater, the higher the temperature of the body ; and from analogy it may be assumed that the agitation is really a definite oscillation, though the paths described may be very complex. Now, ordinary white light, as has already been pointed out in the last chapter, most probably consists of an almost infinite series of undulations of varying length, traversing a medium, and it is quite conceivable that the molecules of a body, whose oscillations synchronise with one of these series of ethereal waves, may have their paths altered in form, and their amplitude increased to such a degree, that a rearrangement of the atoms must ensue. In order to illustrate the effect of one oscillation upon another, the late Professor Rankine employed the following contrivance. A is a lath to which is suspended a leaden bob, B, some six or seven pounds in weight ; C is a string attached to B, by which is suspended a wooden bob, D. The whole is caused to oscillate on an axis placed at X. When the length of the string is such as to cause the heavy and the light pendulum to sychronise accurately, a slight horizontal displacement of B will cause the length of amplitude of the oscillations of D to increase to such an extent that the latter will pass the semicircle and tumble. When the synchronism is only nearly perfect, the amplitude of D will at first increase, gradually stopping the oscillation of B, when it will diminish, and finally come to rest and bring B into oscillation once more, and so on. If we take the swing D as the type of the oscillation molecule, and that of B as the oscillation of the ethereal medium, it will be seen how perfect and nearly perfect synchronism will increase the oscillation of the molecule. The same illustration applies to a part of the theory of explosives, whether caused to

FIG. 5.

explode by the energy of radiant heat, or by that of atmospheric or gaseous waves. This is in accordance with what we have already advanced: it is only those waves which are entirely or partially absorbed, and whose amplitude is consequently annihilated or reduced, which can do work on a body: therefore, in choosing any particular ray of light with which to cause this class of decomposition in a compound, it is a *sine quâ non* that it must be absorbed; in addition to which, some atoms must be less loosely bound to the molecules than are others. It is found practically that the bodies employed for photographic purposes are affected principally by the waves of short length, and that as a rule those of greater length are inoperative; and here we come to a great distinction existing between the rearrangement of the atoms of the molecules, in explosives and in photographic compounds. The short wave lengths do not affect the former, though the longer ones, which we call radiant heat, can do so. Now the *energy* transmitted from a hot and luminous body by the medium lies principally in those waves which are capable of producing what we call heat (in fact the energy can only properly be estimated by ascertaining the heating effect due to the radiations) and as the heat produced in a body by the waves of lengths such as 450 millionths of a millimetre is insignificant, and when they are of a length of 200 millionths of a millimetre is absolutely immeasurable, it it is evident that the energy expended on the production of these last wave-lengths is small; at the same time it happens that their production, *as a rule*, necessitates the existence of those of greater length. Thus, a platinum wire inserted in an electrical circuit may be heated, and yet only radiate dark rays; by increasing the current it may become cherry-coloured, and a spectroscopic examination will demonstrate that only red rays are emitted, whilst at the same time it may be shown that the intensity of the dark rays is increased. By further increasing the current, the

yellow, green, blue, violet, and ultra-violet rays may in succession be caused to radiate from the wire; all the first emitted rays increasing in intensity. The accompanying diagram shows the increase of the red, orange, blue, and ultra-violet rays produced by the expenditure of work in a steam-engine driving a Gramme's magneto-electric machine.

Fig. 6.



The ordinates of the curve show the intensity of the different rays as compared with those emitted from an ordinary wax candle of known weight and rate of burning.

In order, therefore, to displace the molecules of small stability of the photographic compound which are in equilibrium, it is as a rule necessary to produce waves of great length as well as waves of short length, and this may mean the existence of a great heat energy at the primary source of radiation though not necessarily at a reflecting surface. Now the usual result of the displacement of an atom from what we may call the *sensitive molecule* is to form a fresh

solid body, and consequently the potential energy of the molecule is small, also the number of these molecules acted upon in a given time is small in comparison with the total; hence the kinetic energy (which may take the form of heat) that may be generated by the chemical decomposition and recombination falls far short of that required to produce even red light, much less waves of still shorter length. We thus see that although one molecule of an explosive *per se*, after its potential energy has become kinetic, can cause vibrations of such a character as to effect a disruption of the neighbouring molecules, yet a similar disturbance produced in a molecule of a photographic compound is not capable of causing an extension of the action beyond the molecule itself, and that it requires a renewed action of the disturbing force to do it. At first sight this seems unfortunate, but when we consider what would happen were such an event possible, it is apparent that the production of a photographic image in such a case would be impossible.

In a succeeding chapter it will be found that a molecule of chloride of silver responds principally to the swing of the waves in the blue part of the spectrum, and that it undergoes a change, owing to the throwing off of one of its constituent atoms; yet the same body may, by the aid of an artifice, be fused by the dark rays of heat, which are comparatively of great wave-length, and though it in itself becomes luminous, emitting the very same rays that, when falling on it, can cause one of its atoms to be shaken off, yet it remains unaltered. In this last case the vibrations of the molecules are not of the definite character needed to cause the change. A small force, applied at definite intervals, may cause a body to attain a great amplitude of vibration. A boy may cause a violent oscillation of a church bell if he time his pulls at the rope properly, and the accumulated energy may be such that it may drag the ringer up, though the work he may have executed at each pull of the rope may be very small. On the other hand, the ringer

may expend the same amount of energy at the wrong time, and the effect on the bell will be insignificant. The experiment given at p. 14, fig. 5, illustrates this effect.

As before stated, the number of molecules affected in a short interval of time by light may be so small that their change in atomic composition may be invisible to the eye, or in *physical appearance* may be of a similar nature to the compound from which they are derived, in which case even a prolonged exposure to the actinic rays would produce no visible effect. When the sensitive compound is formed in a thin layer held *in situ* on some substratum, such as paper, glass, &c., the light reflected and radiating from an object after passing through a lens may be caused to fall upon its surface and form an image. When the rays are of such a nature as to cause the equilibrium of the constituent molecules to be disturbed, the change will take place only in such parts of the thin lamina as are illuminated ; and thus an *invisible* image formed by the shaken compound may be impressed if the time of exposure be short, or the change produced be such as not to be within the scope of our vision. Otherwise upon long exposure a *visible* image may be produced, the resulting compound being different in appearance from the original.

As the point is of great importance, we must again direct attention to the fact, that the two images are exactly alike in chemical composition, one differing from the other solely in the number of molecules altered. Fortunately, methods exist of rendering visible to the eye what is ordinarily and primarily invisible, and this operation is termed the development of the image. The invisible image is frequently termed latent, an appellation which, though convenient, is yet open to some criticism. We will now discuss the various ways in which development may be effected.

1*st Method.*—The new compound may possess an attractive force. If a rod or wire of zinc be placed in a solu-

tion of lead acetate, chemical operations immediately commence. The outside particles of the zinc enter into combination with the acetic acid of the lead acetate, and particles of lead are deposited upon the rod in their stead. As the action continues the lead further reduced is, by a certain well-ascertained law, attracted to the lead already deposited. Spangles of the metal in a crystalline form attach themselves to the rod and then to one another, until what is known as a lead tree results, just as a magnet will a string of nails suspended from one of its poles. In a similar way a silver tree may be formed from a solution of its salts, provided the reduction be slow. So the action of light on certain sensitive compounds, especially amongst which may be mentioned those of silver, is to cause the formation of a body which is capable of attracting the metal (of which it is itself a salt), when slowly deposited from a solution. This first deposit is capable of attracting still more of the metal, and thus an image is completely built. This action is more fully treated at p. 64.

2nd Method.—The altered compound may be able to effect a reduction to a metallic state of a metal from a solution of its salt, which the original compound may be incapable of doing. In this case the metal would be naturally precipitated on the altered compound, and the attractive force of the freshly-deposited metal would determine the attraction of any other that might be caused by extraneous causes to deposit itself. In this method, as in the last, it is evident that the minutest portion of the altered compound is able to effect a building up of the image. See p. 159.

3rd Method.—The image may be formed by the partial reduction, to a more elementary state, of the altered compounds, when treated with certain solutions, which reduction in the original compound was impracticable; also in this reduced state it may exercise the same attractive force as above. We shall have an example of this in alkaline development. See p. 97.

4th Method.—The altered compound may be capable of forming a coloured body when treated with metallic or other solutions. In this case it is manifest that the image must be due solely to the amount of the sensitive salt originally altered in composition, and its vigour must consequently depend upon the time the light has acted. Of this method of development we shall have examples in the more sensitive ferric salts.

5th Method.—The attractive force of an altered molecule may be utilised by causing metallic or other vapour to condense upon it in preference to the neighbouring molecules which may not have been changed by light. This first condensation may determine the following condensation. Of this we have an example in the development of the daguerreotype plate.

6th Method.—The alteration in the compound may be shown by its incapacity to absorb moisture.

7th Method.—The new compound may be incapable of entering into solution, though the original compound may be readily soluble.

The chemical agents which are utilised in order to allow the development of the latent image to take place will be discussed as each method is brought under particular consideration. It is to be remarked that these agents are technically called developers, a term which, critically speaking, is a misnomer, as in the majority of cases the part they play is a secondary one, and one which they fill whether applied to development or not. The term is convenient, however, and will be adopted in this work, though the student must in his own mind make the reservation indicated when coming across the term.

Intensifying an image already developed or visible is a term applied to a process whereby the image is (1) rendered more visible to the eye, or (2) rendered more absorbent of, and therefore less transparent to, some particular kind of light, be it white, blue, red, yellow, &c. Both of these results

can be obtained by following the methods indicated for developing the image. Fuller information regarding the necessary procedure will be given as various processes are described.

Fixing an image is rather a vague term. It is intended to express that the image due to the first exposure and subsequent development shall be so treated as to undergo no change, leading to obliteration. This is usually effected by clearing the image of all that portion of the sensitive compound which has not been acted upon by light, and thus of rendering it incapable of being obliterated by fresh exposure or appearing indistinct. If the sensitive compound were absolutely colourless, and the action of light were to leave the new compound colourless, the *developed image* would need no clearing or fixing; but, since all the sensitive compounds are either coloured themselves, or are converted by light into others possessing colour, there is evidently no safety, except in their entire removal.

CHAPTER IV.

THE ACTION OF LIGHT ON VARIOUS COMPOUNDS.

THE action of light on various substances must have been a matter of remark from the earliest times. The tanning of the skin, the fading of colours, must all have been noted long before an attempt was made to ascertain the cause of such alteration. However, as we pointed out in the historical sketch, silver chloride was the first substance whose behaviour was philosophically examined; and we propose to study the principal silver compounds before proceeding to other sensitive bodies. Scheele, as we have seen, found that chlorine was given off during exposure from the chloride, and that after treatment of the

blackened body with ammonia, metallic silver was left behind. There is not much need to carry the investigation further than Scheele, only the conclusion that he accepted, viz. that metallic silver was separated at the time of exposure, should be viewed with much doubt, particularly when it is found that the darkening action of the chloride takes place even when immersed in the strongest nitric acid. The accepted theory seems to be that exposure to light reduces any chloride to the state of subchloride, thus :

$$\begin{array}{ccccc} \text{Silver Chloride} & = & \text{Silver Subchloride} & + & \text{Chlorine} \\ Ag_2Cl_2 & = & Ag_2Cl & + & Cl \end{array}$$

When the same compound is moistened the reaction appears to be different, as chlorine decomposes the water with which it is in contact, forming hydrochloric acid (HCl) whilst the other atom of hydrogen and the oxygen atom in the molecule of water combine with another atom of chlorine to form hypochlorous acid ($HClO$). If, instead of exposing the silver chloride in a dry state or in the presence of moisture, it is exposed in presence of free silver nitrate, fresh silver chloride is formed, and this same compound of chlorine and oxygen liberated ; and it is found generally that the darkening takes place much more rapidly when any body which will take up the chlorine is in contact with it. Thus, stannous chloride will cause more rapid darkening, from the readiness with which it absorbs chlorine. The student would do well to repeat the experiments of Scheele and those subsequently indicated, in order to convince himself that these reactions really occur. The easiest method of procuring pure silver chloride is to precipitate it from a solution of silver nitrate by an excess of pure hydrochloric acid, and to wash it thoroughly by decantation, repeating the washing to such a point that the supernatant water shall no longer show acidity when tested with blue litmus paper. This method of procedure prevents the possibility of contamination by the organic matter of filter paper. The

silver chloride, if required in a dry state, should be dried in the dark over a water-bath, in a watch-glass or porcelain capsule. A test-tube is a convenient vessel in which to give the exposure to the light, and the subsequent washings are conveniently carried out by simple agitation and pouring off the liquid. A note-book should invariably be at hand in which to describe the phenomena that may be observed in these or any other photographic experiments, and it will be found convenient to attach consecutive numbers to each. It must ever be remembered that there is no experiment properly carried out, with a set object in view, which is not worthy of record. The most trivial deviation from the expected results of an experiment often causes some new line of thought to be taken up, and may suggest important investigations.

The next silver salt that requires a careful study is the iodide; and it is owing to certain peculiarities in its behaviour when exposed to light, that so much difficulty has arisen in defining the true changes that take place in it.

Silver iodide may be produced in two or more ways. The most common is by treating a silver nitrate solution with a soluble iodide, such as ammonium. If the former be in excess, even in minute proportions, after most careful washing, it will be found that the compound darkens slightly on exposure to light, whilst if the latter be in excess, there is no apparent change in colour. To explain this last phenomenon, it must be remembered that the bonds of attraction between the iodine and the silver atoms of an iodide of silver molecule are much less readily broken than those of the constituent atoms of the chloride or bromide; for we find that there is greater amount of heat generated in the formation of the former than in the two latter, and that, therefore, the separation of an atom of iodine from the molecule of silver iodide (Ag_2I_2) is much less readily effected than is that of the chlorine from the chloride or bromine from the bromide; and, when we come to consider the effect of the

impact of light on such molecules, we shall readily understand the difficulty that exists in causing it to change. The shocks which will break up the chlorides or bromides are insufficient to produce any alteration when nothing but pure iodide is present.

When, however, there is an excess, however slight, of silver nitrate, the conditions are quite altered; for then there is a compound at hand which is ready to seize any iodine which may be brought near it. Thus, when the silver nitrate is present, the molecule of iodide is at once changed in chemical composition, and a subiodide is formed in a similar way to the formation of subchloride from the chloride.

$$\text{Silver Iodide} = \text{Silver Subiodide} + \text{Iodine}$$
$$Ag_2I_2 = Ag_2I + I.$$

It may here be remarked that in one respect iodine is unlike chlorine in behaviour; it is incapable of forming hypoiodous acid (HIO), though chlorine, as already pointed out, forms HClO; hence there is some difficulty in ascertaining theoretically the exact reaction which takes place between the liberated iodine and the silver nitrate which is necessarily present to produce the change.

A simple experiment, however, which it is well to repeat, throws light upon it. Take washed silver iodide, and place it in a test-tube containing in solution silver nitrate which has previously been thoroughly boiled in order to expel any air which it may contain. If an air-pump or an exhausting syringe be at hand, the boiling may be dispensed with, and the same end attained by creating a vacuum in the tube. Now expose to light; in a short time bubbles of gas will be found collecting in the solid iodide, and with care these may be collected, and on testing by the ordinary means will be found to contain oxygen. From this we may suppose that the liberated iodine decomposes the water in contact with it (as does chlorine), and produces hydroiodic acid (HI) and oxygen.

The former combines with the surrounding silver nitrate, and we have a total reaction, as follows :—

$$\begin{array}{ccccccccccc} \text{Silver Iodide} & + & \text{Silver Nitrate} & + & \text{Water} & = & \text{Silver Subiodide} & + & \text{Oxygen} & + & \text{Silver Iodide (newly formed)} & + \\ Ag_2I_2 & + & AgNO_3 & + & H_2O & = & Ag_2I & + & O & + & AgI & + \\ & & & & & & \text{Nitric Acid} & & & & & \\ & & & & & & HNO_3 & & & & & \end{array}$$

If any iodine absorbent be placed in contact with washed silver iodide, prepared with an excess of soluble iodide, the reaction that takes place is apparently more simple, the iodine atom combining directly with such a body. It may thus be stated as a law that *in order to produce a change by the action of light in silver iodide, some body must be present which can absorb iodine.*[1]

There are one or two suggestive experiments which may impress this on the mind. The first is to silver a glass plate as if for a mirror, and then to expose it to the action of iodine vapour (as in the daguerreotype process) to such a degree, that the whole of the extremely thin film of metal is converted into iodide. On exposing such a plate to sunlight no change is visible, nor can one be brought to the cognisance of the senses by bringing developing agents in contact with it. If the film be not wholly converted into iodide, this result will not occur, as the metallic silver is an iodine absorbent. Another experiment, which is very conclusive, is as follows : Prepare a film of silver iodide, as in the wet process, and immerse it in potassium iodide solution till any excess of silver nitrate is converted into silver iodide, and wash thoroughly for an hour, and dry. Next take a small square piece of silver leaf and apply it to one portion of the iodide surface, brushing it well down, in order that real contact may be obtained. To another small portion apply a solution of tannin in alcohol, and after drying expose the plate to the

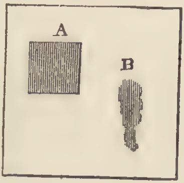
[1] This law seems to have been first emphatically enunciated by Vogel, though a claim has been made by Poitevin.

light. On developing, as indicated at p. 103, a darkening action will be apparent after a short interval of time on those portions of the plate treated with the silver leaf and the tannin.

The action will be most intense in the latter, as might naturally be expected, the whole thickness of the iodide being in the one case brought in contact with the absorbent, whilst only those particles which form the surface are brought in contact with it in the latter. The experiment is more telling if the plate be exposed behind a negative, with the uncoated side next the image.

If instead of the silver leaf a thin silvered plate be pressed into firm contact with a sensitive collodion film, prepared as above, it will be found that even a fair exposure is sufficient to cause the formation of an image on both, which, though unrecognisable to the senses, is yet capable of being developed by the proper methods. This experiment thus serves to show conclusively that iodine is liberated by the impact of light; for, were the change one merely of molecular arrangement (as many enquirers have held to be the case), no image could be formed on the metal plate, the possibility of developing an image on it being dependent on the presence of silver iodide (see the daguerreotype process).

Fig. 7.



The behaviour of silver bromide is similar to that of silver chloride; hypobromous acid being formed under similar circumstances to those in which hypochlorous acid is produced. The chloride and bromide are both soluble in ammonia (which is an important point when dry plate processes are considered), whilst the iodide is not. It may be here recorded that with the chloride and bromide, as with the iodide, the presence of silver nitrate increases sensitiveness to a very high degree.

Besides the salts already mentioned there are other in-

organic compounds of silver, such as the fluoride, phosphate, silicate, which are altered by the action of light, but these are comparatively unimportant. There are, however, certain organic compounds formed, the action of light upon which can only be briefly noted here, though a fuller description of the phenomena will be given in a subsequent chapter.

When organic matter is brought into contact with a soluble salt of silver, a definite compound is often formed, and the effect of impact of light upon this is somewhat complex to trace. Thus, if we form an albuminate of silver by bringing a solution of silver nitrate in contact with one of albumen, and expose it to light whether there is an excess or defect of the silver salt present, a darkening of the compound results.

The blackened compound is not a true silver oxide, though chemical considerations lead us to infer that the colouration is dependent on the formation of silver oxide, in combination with organic matter. The same results are obtained if gelatine or other kindred body is substituted for albumen. It will be as well if the student experimentally compare the effect of light on an organic silver salt with that on silver chloride, as both are employed in the silver printing process.

The following experiments will naturally suggest themselves. Take sodium chloride and dissolve in water and add an excess of silver nitrate to it, by which we have precipitated silver chloride formed; also take the same solution and allow the sodium chloride to be in excess. Carefully spread the moist chloride on pieces of glass, and expose to light. Both will readily darken, more especially the former, which will gradually assume an inky black tint, whilst the latter remains a pale violet. From what has already been said, the cause of this phenomenon will be apparent, the chlorine liberated in the first case is rapidly absorbed, whilst in the second it is merely held in

solution, clinging as it were to the silver subchloride, and ready to reduce it back to the same state as before. If to the silver chloride, in which the sodium chloride is in excess, we now add a little stannous chloride which is ready to absorb chlorine, the blackening will proceed as rapidly in the one case as in the other. Now treat all these residues with nitric acid, and they will all be found to remain unattacked by it, but instantly yield to a strong solution of sodium hyposulphite, leaving metallic silver in small quantities behind. Next precipitate albumen in excess, or otherwise of silver, and expose to light; the darkening will proceed more rapidly and to a greater depth in the one case than in the other. Treated with ammonia but little alteration is visible, but on applying nitric acid, the oxide at once disappears. If, however, it be treated with sodium hyposulphite, it will remain nearly unaltered in appearance. Next treat the undarkened albuminate of silver with hyposulphite, and it will dissolve, leaving a milkiness in the solution; on further adding ammonia to the solution, however, this will disappear entirely. If both the darkened bodies are treated, after the sodium hyposulphite has been applied, with a solution of hydrogen sulphide (H_2S), the former will blacken from the formation of silver sulphide, the latter will bleach from the formation of a new organic compound; the bearing of this experiment will be seen when we consider the fading of silver prints.

Again, to a similarly treated precipitate of chloride and albuminate add potassium cyanide; the one will be but slightly acted on, whilst the other will be speedily attacked. In determining the fixing agent to employ in silver printing, this point has to be taken into consideration. If experiments with other organic bodies be carried on in a similar manner, it will be found that the same phenomena will be observed; the distinction between the nature of the reduced organic compound will be seen in the different colours they assume.

From these simple experiments, then, we learn, that the

darkening action of silver chloride is aided by the presence of a chlorine absorbent; that the subchloride thus formed is unaltered by nitric acid (in fact the darkening action takes place as rapidly in the presence of nitric acid with silver nitrate as if the latter be alone in excess); that the subchloride is split up by sodium hyposulphite into metallic silver and silver chloride, the latter being destroyed by it as shown at p. 74. That in organic matter which forms a compound with silver nitrate, when acted upon by light, the silver is reduced to a state of organic oxide, and that the presence of an excess of silver nitrate is not absolutely necessary; that the darkened compound is unaffected by sodium hyposulphite; that potassium cyanide is a solvent of this oxide, and not of the metallic image formed from the sub-chloride.

The next metallic salts to which we shall refer, in regard to their behaviour when exposed to light, are those of iron and uranium. Their reactions are almost precisely similar. To Sir John Herschel we owe most of our knowledge of the iron compounds; whilst to Niépce de St. Victor is probably due the discovery of the particular properties of uranium. If we brush over a piece of paper a neutral solution of ferric chloride, and, after allowing it to dry, expose it to light, the yellow colour imparted to it will be found gradually to disappear, leaving the surface apparently bleached. If, now, we allow a solution of potassium ferri-cyanide to flow on to the exposed paper, it will be found that a deep blue colouration is immediately produced, whilst if applied to the unexposed paper no such phenomenon would be observed. From chemical experiment we know that, in order to produce the blue precipitate, it is necessary to have in contact with the potassium ferricyanide some ferrous compound. Since it was a ferric compound, viz. ferric chloride, which was applied to the paper, we are led to conclude that the action of light has been to reduce this salt to the state of ferrous chloride.

By similar experiment we become convinced that the

action of light on all ferric salts, *under certain conditions*, is to reduce them to the ferrous state. It may be remarked that in order to produce the requisite reduction, the presence of organic matter, such as the size of the paper, with some of these iron salts seems a necessity; if this be absent, the action is very slow. And, again, the organic compound should be of such a nature that it is ready to combine with the atoms thrown off, in the same way as that already indicated for silver iodide. There are a variety of bodies which will combine with these atoms; but unfortunately, as a rule, they have a greater affinity for the atoms than has the iron compound with which they are only loosely combined. The organic matters with which they will combine without being torn away from the iron are rather slow absorbents, and therefore generally the sensitiveness is not great. For, as with the silver iodide, the sensitiveness depends chiefly on the readiness of the neighbouring matter to absorb what is thrown off.

In order, then, for iron salts to become as sensitive to light as silver salts, some body must be found which, *per se*, will not reduce them to the ferrous state or decompose them, yet which, when the atom is liberated, will seize it with greater facility than any body with which we are as yet acquainted. As a rule, the development of these pictures is carried out by either method 2 or 4 (p. 19), the details of which will be given in the section on printing with these salts. Since these compounds are comparatively but little sensitive to light, they are chiefly used for obtaining positive prints; an exposure in the camera to produce a developable image would have to be very prolonged.

The same experiments carried out with regard to the uranium compounds give identical results. The uranic compounds are reduced to uranous, and the methods of development are similar.

To the same class of metals belongs vanadium, the interesting compounds of which were investigated by Professor Roscoe. The reactions are similar to the above.

The last metallic compounds to which we shall refer at length are those of chromium combined with the alkalis.

The salts found most sensitive to light are the dichromates, though the chromates are also, to a certain extent, capable of being acted upon. Mungo Ponton first indicated the principle which governs their employment. If a solution of a dichromate, such as that of potassium, be brushed over paper, and be allowed to dry, and be then exposed to light beneath an engraving, it will be found that in those portions corresponding to the white paper the orange colour will gradually assume a delicate brown tint, whilst on the parts shaded by the lines the salt remains unchanged. The eye then at once tells that some chemical change has taken place in the chromium compound. Chemists are accustomed to employ the dichromate to convert a ferrous salt into a ferric, and by having it in a solution of known strength, and ascertaining when the reaction is complete, the amount of iron in the ferrous solution can be estimated quantitatively. Thus we have, say, the amount of ferrous chloride to test quantitatively: the amount is calculated by applying the following equation:

$$\underset{6\,FeCl_2}{\text{Ferrous Chloride}} + \underset{K_2Cr_2O_7}{\text{Potassium Dichromate}} + \underset{14\,HCl_6}{\text{Hydrochloric Acid}} = \underset{3\,Fe_2Cl_6}{\text{Ferric Chloride}} + \underset{2\,KCl}{\text{Potassium Chloride}} + \underset{Cr_2Cl_6}{\text{Chromic Chloride}} + \underset{7\,H_2O}{\text{Water}}$$

It will be seen that the potassium dichromate readily parts with its oxygen and potassium, and becomes converted into a pure chromium compound. The change induced by the light is analogous to this, there being every reason to believe that the following equation is a type of the reaction that occurs—

$$\underset{C_xH_2{}^{+}{}_2O_2}{\text{Organic Matter}} + \underset{K_2Cr_2O_7}{\text{Potassium Dichromate}} = \underset{2\,KHO}{\text{Potassium Hydroxide}} + \underset{Cr_2O_2}{\text{Chromic Oxide}} + \underset{C_xH_yO_{z+2}}{\text{Organic Matter}}$$

An analogous reaction of a chromium salt in the presence of an organic compound, without the impact of light, is found in chromium trioxide. If alcohol be dropped on these dry crystals, oxygen is evolved so rapidly that the spirit is ignited by the energy of the act of combination. Now the dichromate contains less oxygen than the acid (H_2CrO_4) formed by the trioxide (CrO_3), hence the evolution of oxygen from it is likely to be less easily effected by organic matter than from the latter. The swing caused by the waves of light is sufficient to effect the change, that is indicated by the equation above. It will be noticeable that not only is the chromium compound altered in composition, but that also the organic matter is deprived of hydrogen; and it is the fact of this deprivation, or change in organic matter, that renders the dichromates valuable for photographic purposes. It will be found, after experiment, that the dichromatised paper prepared as above is nearly insensitive when moist, and that the image can be formed most readily when it is dry. The reason of this is probably that when dry the organic matter and dichromate form a real compound, which is, however, readily split up on remoistening. If, however, the contact be long continued, an alteration in the position of the atoms of the molecules probably commences. This might account for the insolubility of old carbon tissue, and it may be presumed that the change which is rapidly effected by light is much more slowly accomplished by the long contact even in the dark.

The development of pictures taken on ordinary sized paper is usually effected by method 4 (p. 20), and will be noticed when treating of the aniline process. When, however, the paper is coated with a layer of organic matter, such as gelatine or albumen, the development of the picture may be effected by methods 6 or 7. Colloidal bodies available for photographic purposes, when oxidised, are changed in physical as well as in chemical properties. 1st, they cannot after oxidation be dissolved by water, either

hot or cold, though before oxidation they may be easily soluble. 2nd, they will not *absorb* water, and consequently will not increase in bulk, if the impact of light be prolonged. These modes of development will be entered into fully when treating of the carbon and collotype printing processes.

It is scarcely necessary to refer to the salts of other metals; they are mostly too insensitive to the action of light even for contact printing. Robert Hunt, in his excellent 'Researches on Light,' has entered fully into the phenomena observable with most of these compounds, and the student should study that work for further information.

Of organic bodies there are a variety which respond to the chemical vibrations. First and foremost, as being of practical utility, is the substance known as asphaltum, or bitumen of Judæa. It is the substance which was first employed by Niépce for practical photography, and it still retains its place amongst useful photographic compounds. It is readily soluble in a variety of menstrua, such as benzole, chloroform, and turpentine. After exposure to light, it loses its excessive solubility, and it is not only possible, but practicable, to dissolve away from a thin layer of it all those portions which have not been acted upon by light. For certain photo-engraving and relief-printing processes it is still employed, on account of its resistance to the action of acids (see p. 182). It seems that during exposure it becomes oxidised to a certain extent.

Amongst other sensitive organic compounds may be named the extracts of flowers and leaves and certain dyes. These are more interesting than useful, and it is sufficient to mention them.

Among gaseous bodies which are sensitive to light we may name chlorine, when exposed in the presence of hydrogen. If in a dimly lighted room the proper combining volumes of these two gases be mixed in a glass bulb, or other convenient holder, and then exposed to the direct rays of

the sun, or other strong source of light which emits the shorter wave-lengths, it will be found that they combine with explosive violence to form an equal volume of hydrochloric acid. In diffused daylight the combination takes place much more quietly, and attempts have been made to utilise this action to measure the 'actinism' of any light to which it may be exposed (see 'actinometry'). The affinity of chlorine for hydrogen is so great that it causes a decomposition of the water in an aqueous solution, when exposed to the light, though it has no power to do so if kept in the dark.

The latest discovery of light causing a combination between a gas and a solid is due to Mr. Francis Jones, of Manchester. He found that in sunlight, if sulphur was brought in contact with antimoniuretted hydrogen or stibine, the orange sulphide of antimony was formed. The equation representing the reaction is as follows:—

Antimoniuretted Hydrogen + Sulphur
= Antimony Sulphide + Hydrogen Sulphide

$$2\,SbH_3 + 6\,S = Sb_2S_3 + 3\,H_2S.$$

With arseniuretted hydrogen ($As\,H_3$) a like reaction takes place.[1]

After this brief *résumé* of the sensitive compounds the student will at once distinguish the advantage to be gained by the employment of the simpler salts of silver for obtaining images in the camera. It is these alone which are susceptible of rapid development by exercising an attractive force when the altered molecules are few in number; whilst all the other compounds require a large number of particles to be changed in order that the image may be made visible at all. With the iron salts *per se* the development by attraction may be resorted to; but it will be found on experiment that the attractive force is so small that it does not nearly equal that of the silver compounds. Hence we may assert that, for producing developable images in the camera, the chief portion of the sensitive salt must consist of one of these silver salts,

[1] As being substituted for Sb in the above equation.

and that other metallic salts can best be utilised for obtaining impressions by long exposure, and are therefore chiefly adapted for obtaining positive proofs from negatives.

CHAPTER V.

ON THE SUPPORT AND SUBSTRATUM.

IN judging of the kind ot support on which to receive an image, whether it be developed or formed by the continued action of light, it must be considered for what purpose the image is to be employed. If it is to be employed as a screen, or a negative from which to form a picture complementary to it in photographic density and position, then evidently the more transparent the support is, the better it will be for this particular purpose. As a rule, it is only images impressed in a camera which are employed as 'negatives,' and as these may be said to be invariably taken upon the sensitive salts of silver, which are easily acted upon chemically by extraneous matter, it is evident that a substance should be employed which is unaffected by them and by the agents which cause the development of the image. In addition to this quality, a certain amount of rigidity in the support is convenient, though not essential, as the operations involved are of such a character as to cause this to be a desideratum. Evidently glass answers the object most thoroughly. Less fully does paper when waxed answer these requirements; for with it there is translucency and not transparency, and none of the other qualities. A support of collodion and india-rubber combined, such as recently has been advocated by Warnerke, answers to the first two requirements, and, since the operations involved in his method of working do not necessitate rigidity, it is a suitable one.

To give a correct idea of an image by reflected light, that is, to look at it as a picture is looked at, it should appear as highly coloured or as black as possible when contrasted with the ground on which it rests. Formed by development (after exposure in the camera), it possesses always more or less density, the density *approximately* varying inversely as the intensity of the reflected actinic light which has acted on it. If the developed image be of a dark colour, the proper effect of light and shade will be reversed. To give a correct representation, the deposit must be *transparently white*, and the support dark-coloured or black. In the daguerreotype process the support is a metal plate, which is by contrast dark when compared with the mercurially-developed image. In the collodion process, if the image can be made to appear white by reflected light, the support may be of glass, if it be backed with some dark-coloured substance, such as black velvet or varnish, or it may be of metal darkened with some substance that is unaffected by the chemical agents employed (an example of this we have in the ferrotype plates). On the other hand, if the picture be produced by a subsequent operation from a negative, the image should be as *transparently dark* as possible, and the ground white. In this case the support (unless other considerations forbid it) may be white paper, opal glass, or any other white medium. It is also worthy of notice that in order to produce a proper representation of light and shade the ground should always be in contact with the image. An example of a certain false gradation given in an image, in which this important rule is neglected, is to be found in the old collodion positives on glass.

Heretofore nothing has been said regarding the vehicle employed for holding the sensitive compounds *in situ* on the support, and this requires a detailed consideration. It need scarcely be said that some sort of vehicle is generally necessary. The fact that most of the compounds employed

for photographic purposes are solids, and whether formed by precipitation from or evaporation of a solution are in a pulverulent state, at once clearly demonstrates the necessity. We must distinguish between two cases.

1. In the case in which the image is formed by development, it is essential that the developing agent should cause no chemical change or discolouration in it any more than in the support. Now the sensitive compounds may be formed in the support itself. Thus a solution of potassium bromide brushed on to paper, and then followed by a similar application of silver nitrate, will cause the formation of silver bromide in the paper. The paper will in this case act as a support and vehicle too. An invisible impressed image can be developed on it, but it would be found that it is liable to stains due to the organic matter of the sizing. It is also only translucent and not transparent. And it is therefore, as a rule, unadvisable to use it for holding the sensitive compounds *in situ* when 'negatives' are required. Again, if the support be not at the same time a medium, it is essential that the latter should adhere to the former during the operations of development.

2. When the image is to be formed entirely by the direct action of light, the above conditions are not a necessity. Then paper will be suitable for a medium, as there is nothing extraneous to the sensitive compound to act upon it. At the same time there is nothing to forbid the employment of all other vehicles which are not acted upon by the sensitive compound. In the production of camera pictures collodion is almost exclusively[1] employed; and it is particularly suitable for holding precipitable silver compounds in position, as it is a ready solvent of most of the bodies which it is necessary to use, and the precipitation can be effected in the viscous collodion itself. The silver compounds are thus formed in a finer state of division than they would be if precipitated from an aqueous solution. This point is most important, for

[1] For exception see the gelatino-bromide process, p. 124.

light impacts upon surfaces: and as the surfaces of similar particles increase as the square of the diameter, whilst their masses increase as the cube, it is evident the smaller the particles are the larger will be the available area for the same quantity. Collodion is a transparent, semi-viscous fluid, made by dissolving pyroxyline (gun-cotton) in a solution of ether and alcohol, and is for ordinary purposes totally unacted upon by the sensitising solution of silver, though, when specially prepared, it is believed that an organic compound of silver is formed. Other advantages of collodion are to be found in the property it has of setting in a gelatinous form, previous to its final desiccation, and also that the solvents used evaporise rapidly at ordinary temperatures, leaving the salts, which are to form the precipitate, if not in solution, yet with their individual particles in such an extremely minute state of division as to be undistinguishable to the eye.

Gelatine and albumen are equally good solvents of the salts alluded to, but they have the drawback that they take long to set, and dry very slowly, and at the same time they form definite compounds with silver.

CHAPTER VI.

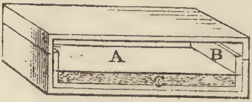
THE DAGUERREOTYPE.

UNDER the head of silver processes, the first that would naturally occupy the attention is that due to Daguerre. It is even at the present date adopted for some kinds of work; for instance it was employed by the French expeditions, sent to observe the transit of Venus in December 1874.

The daguerreotype process consists, as already stated, of the formation of a sensitive surface of silver iodide, or silver iodide and bromide, on a silvered plate, by means of the direct

action of iodine, or iodine and bromine. One of the most difficult (and difficult only because the greatest cleanliness in every detail is required) parts of the whole process is the preparation of the silvered surface before its coming in contact with the halogen. The plates are usually copper, on which a film of metallic silver is deposited by the electro-plating process, and when they leave the silvering solution have, as a rule, a frosted appearance. After being cut to the proper size, and the corners clipped of about $\frac{1}{8}$th of an inch for convenience' sake, they are ready for polishing. A plate in this state may be placed on a flat table, and four thin strips of wood nailed round it to prevent it slipping. To the surface is then applied tripoli powder in alcohol with Canton flannel, and worked about to such an extent that it is perfectly free from scratches, and is fairly smooth. The next operation consists in polishing it. This is effected by means of a buff. That which the writer has found effective is made by enclosing a wooden ball, of the size of a small apple, in a skin of felt and then of cotton wool. Over this is stretched a piece of the finest Chamois leather. On to the surface of the silver is then scattered a small quantity of jeweller's rouge, and the buff is caused to travel over the plate from end to end and side to side alternately till it becomes of the highest polish. This polishing should take place almost immediately before the sensitising operation is commenced, otherwise there is a liability of the surface attracting impurities from the atmosphere. To sensitise the plate two sensitising boxes are required. An illustration of that employed when daguerreotype

FIG. 8.



was commonly practised for portrait work will give an idea of the sort of contrivance required. On the bottom of the box C is placed iodine in powder ; A is a piece of cardboard, which fits into grooves as shown. B B are the sup-

ports on which the silvered plate is to rest.[1] The iodine will volatilise at ordinary temperatures, and condense on the surface of the cardboard next to it. When a plate is to be sensitised the cardboard is reversed, and the iodine volatilises from the top surface on to the silver plate. The plate gradually receives a thin coating of iodide, passing through various stages of colour. When a ruddy colour is reached, it is placed in a similar box to that already described (omitting the cardboard), at the bottom of which is a mixture of bromine and calcium hydrate. The bromine attacks the surface, and with the iodide forms silver bromo-iodide. When the surface assumes a steel-gray or violet colour the plate is removed, and once more placed in the iodine box for a third of the time originally necessary. In this state the plate is exceedingly sensitive, and is ready for exposure in the camera. The exposure may be made at once, or it need not take place for several hours; Claudet, in fact, found that, by keeping, the sensitiveness increased. The time necessary to impress an invisible but developable image is very short, a few seconds being all that is necessary. Practice alone can tell the exact time required, but it is soon learned approximately after a few trials. The development is accomplished by exposing the impressed surface to the vapour of mercury. A cast-iron tray, with wooden sides and lid, is convenient: it may form a box similar to that shown for the iodising operation. At the bottom is placed a thin layer of mercury, the temperature of which is raised to about 150° Fahr. The plate is placed in the box, face downwards, on the supports, and the development is allowed to proceed, the process being watched as it progresses by inspecting it from time to time in a non-actinic light. If the exposure be right the image will be brilliant, if under-exposed it will be weak; whilst if over-exposed it will be covered with a veil of mercury.

[1] When smaller sizes are to be used they may be held in frames similar to the inner frames of a camera slide.

The development, it will be remarked, is due to the attraction of the subiodide for the metallic mercury vapour, and to no other cause. In order to fix the image the plate is immersed in a 10 per cent. solution of sodium hyposulphite. After a few seconds the unaltered iodide Ag_2I_2 and the AgI of the subiodide (Ag_2I) are dissolved away, and the image is left as a white amalgam of mercury and silver on a darker coloured background. After a thorough washing in distilled water the picture is permanent, but its appearance may be improved by toning it; i.e. intensifying it with gold to darken the silver, and render the amalgam still purer in colour. This is accomplished by pouring over it, in such a quantity as just not to run over the edges,

1.	Gold trichloride	·1 gramme.
	Distilled water	50 cc.
2.	Sodium hyposulphite . . .	·4 gramme.
	Distilled water	50 cc.

The two solutions are well mixed together, and, after flowing them on the plate, a spirit-lamp is moved about beneath its bottom surface, until the toning action commences. The more rapid the deposition of the gold, the more satisfactory the image. When complete, the plate must be well washed in a dish of cold water, and finally rinsed with distilled water. Drying is best accomplished by gentle heat, applied first at one end, and gradually moved down. Any large drops of water should be absorbed by blotting-paper.

Daguerreotypes may be reproduced by electrotypy, if the plate be immersed almost immediately after toning in the copper solution. The ordinary electrotyping process answers every purpose: for the details, reference must be made to books treating specially of the subject. The fact is mentioned here, as it shows that the image, after all these operations, is *in relief*, though naturally to a very limited extent, yet still sufficiently to cause the reflected light to give all the necessary gradations of light

and shade. Sir W. Grove also introduced a method of etching daguerreotype plates by means of the battery. He immersed the plate in a solution of hydrochloric acid two parts, and water one part, and opposed by a platinum plate placed at ·2 inches from it. When the current was generated by a couple of Grove's cells, an oxy-chloride of silver was formed, and after thirty seconds the plate was found to be sufficiently bitten. The oxy-chloride was removed, and for *fine* work was found of sufficient depth to allow it to be printed from with printer's ink in the printing-press. This process has not come much into vogue, as it is one which is too delicate for ordinary operations, and the silvered copper is expensive in comparison with the other metals employed for the purpose. The most recent development of photo-engraving and the production of reliefs are described in a subsequent chapter.

CHAPTER VII.

COLLODION.

PYROXYLINE is prepared by acting upon cotton, paper, or other kindred substances with a mixture of nitric and sulphuric acids. For an example of the process we may take cotton, which has a definite formula of $C_6H_{10}O_5$. Sulphuric acid has the property of absorbing water from any organic substance with which it is in contact; for instance a drop of oil of vitriol on cloth or paper rapidly chars it, owing to the destruction of the constituent atoms, through its affinity for water. Thus, if we take the cotton itself, it will be seen that each molecule contains 6 equivalents of carbon, and just sufficient hydrogen and oxygen to form 5 molecules of water; the oil of vitriol is thus capable of splitting up the molecule of cotton, appropriating the 5 molecules of

water, and leaving the carbon behind.[1] Another good example of the abstraction of an equivalent of water from a molecule is in that of ethyl alcohol, or spirits of wine. If this be distilled over in the presence of concentrated sulphuric acid, we have ether [2] as the product. When the acid is diluted with water, its destructive power is limited, though as the water evaporates from it the power returns.

Now the strongest nitric acid which is usually obtainable contains a large proportion of water. Thus nitric acid, if 1·457 at 60° F. contains only 84 per cent. of HNO_3, hence it is that when this is mixed with sulphuric acid, the water is abstracted from it, and the true nitric acid (HNO_3) is left to act on any body with which it is brought in contact. This is undiluted, and is capable of acting on cotton in a somewhat peculiar way. It abstracts either 2 or 3 atoms of hydrogen (according to the strength of the acids employed, and the temperature), and replaces them by 2 or 3 molecules of nitrogen tetroxide (NO_2) with the formation of water. The formula stands thus :—

$$\underset{C_6H_{10}O_5}{\text{Cotton}} + \underset{2\,HNO_3}{\text{Nitric acid}} + \underset{H_2SO_4}{\text{Sulphuric acid}} + \underset{Aq.}{\text{Water combined with the nitric and sulphuric acids}}$$

$$= \underset{C_6H_8(NO_2)_2O_5}{\text{Pyroxyline}} + \underset{H_2SO_4}{\text{Sulphuric acid}} + \underset{2\,H_2O + Aq.}{\text{Water formed by the decomposition of the cotton, and that combined with the acids}}$$

Or,

$$\underset{C_6H_{10}O_5}{\text{Cotton}} + \underset{3\,HNO_3}{\text{Nitric acid}} + \underset{H_2SO_4}{\text{Sulphuric acid}} + \underset{Aq}{\text{Water}} = \underset{C_6H_7(NO_2)_3O_5}{\text{Gun Cotton}} + \underset{H_2SO_4}{\text{Sulphuric acid}} + \underset{3\,H_2O}{\text{Water}} + \underset{Aq.}{\text{Water.}}$$

[1] It is for this reason that if the most dilute sulphuric acid be spilt on the clothes, or passed through a filter-paper, and be allowed to dry, a charring takes place. In the first case neutralisation with an alkali, or in the second very thorough washing, will prevent the disaster.

[2] Hence the name sulphuric ether. The following equation exhibits the reaction.

$$\underset{C_4H_{12}O_2}{\text{Ethyl alcohol}} = \underset{C_4H_{10}O}{\text{Ether}} + \underset{H_2O}{\text{Water abstracted by the sulphuric acid}}$$

The first being the gun-cotton, as used for collodion, and the second being the well-known explosive compound. It will be noticed that the sulphuric acid remains unaltered in composition, its sole function being to absorb the water formed by the operation. The fact of the existence of the tetroxide of nitrogen in the altered cotton can be demonstrated in its combustion in an exhausted glass vessel by the red fumes which tinge the gaseous products.

The same reaction as the above can be obtained by employing potassium nitrate (KNO_3) instead of the nitric acid, though in this case a portion of the sulphuric acid becomes converted into potassium sulphate. Thus :—

$$\begin{array}{ccccccc} \text{Potassium nitrate} & + & \text{Sulphuric acid} & = & \text{Potassium sulphate} & + & \text{Nitric acid.} \\ KNO_3 & + & H_2SO_4 & = & KH(SO_4) & + & HNO_3. \end{array}$$

The above equations represent the reaction that theoretically takes place when cotton is treated with nitric and sulphuric acid in the above proportions, but there are other points to be attended to in practice.

The proportion of the acids to each other materially affects the properties of the pyroxyline. Sulphuric acid parchmentises paper when it is immersed in it or floated in it, that is, renders it tough and of close texture. The chemical effect produced by the sulphuric acid is hardly known, but if prolonged, it is known that the paper is dissolved. Parchmentised paper treated with nitro-sulphuric acid has different qualities to that in which the parchmentising is omitted. With the former a tough collodion results, though it is more powdery. An excess of sulphuric acid beyond that necessary to produce the reaction shown in the equations acts in a similar way to treating the cotton first with the acid, for it partially parchmentises the cotton previous to its conversion into pyroxyline, and as this is beneficial to a collodion, when not carried beyond proper limits, an excess of this acid is always employed.

The amount of dilution of the acids with water also

largely modifies the resulting compound. When little or no water is added, the pyroxyline gives an unevenly flowing collodion which is strongly contractile when drying. When a large proportion of water is added, the collodion is limpid, flows readily, and is apt to give a matt appearance on drying. By increasing still further the amount of water, the cotton when immersed will entirely dissolve in the acids. Evidently then a mean between no water and the amount necessary to produce dissolution should be employed.

The effect of the temperature of the acids on the cotton is also marked by the behaviour of the resulting pyroxyline, as the effect of heat is to aid chemical change. Pyroxyline made at low temperatures forms a collodion that is always glutinous and difficult to flow over a plate, whilst the higher the temperature the more easily will it flow. It should be remarked that the same effect is produced by the addition of more or less water to the acids. It is, therefore, possible by diminishing the amount of water and increasing the temperature to obtain the same amount of fluidity in a collodion as would be gained by the full amount of water at a lower temperature.

With the above facts before us we can evidently manufacture various qualities of pyroxyline which may be suitable for different purposes. With the wet process, where a solution of silver nitrate comes in contact with the soluble iodides, &c., dissolved in the collodion, its conditions should be :—Firstly, that it should be fairly porous; and, secondly, that it should be fairly tough. This is effected by adding a moderate proportion of water to the mixed acids, and by immersing the cotton in it at a medium temperature.

The following are the proportions which Hardwich (who was the first to thoroughly investigate the manufacture of pyroxyline fit for collodion) states should be observed :—

Sulphuric acid, sp. gr. 1·842 at 15° C.	. 500 cc.
Nitric acid, sp. gr. 1·456	. 166·6 cc.
Water	. 145·7 cc.

The nitric acid and water are first poured into a strong glazed porcelain dish, and well mixed, the sulphuric acid is added last, the liquid being kept well stirred as it is poured in. The temperature will generally rise to 75° or 85° (if to the latter, it may be suspected that the acids are too dilute), and it must then be allowed to cool gradually to 65°. A dozen balls of cotton wool,[1] weighing about $1\frac{1}{2}$ grammes each, having been prepared, should be immersed separately in the fluid, and after thorough soaking (assisted by a glass or porcelain spatula, fig. 9), be allowed to remain at the bottom of the vessel. The immersion should take place rapidly, otherwise decomposition takes place, and this, when once commenced, will cause the temperature to rise rapidly, and the whole of the cotton will be dissolved with the evolution of nitrous fumes. The balls must be left in the acid from ten minutes to a quarter of an hour, and they are then presumably in a state ready for washing. The longer the immersion, the more likely are they to become insoluble in ether and alcohol, approaching more nearly the state of explosive gun-cotton. They are next raised by the spatula, the excess[2] of acid as far as possible squeezed out of them against the side of the vessel, and then they are dashed into a vessel holding a large quantity of water. All traces of the acids are eliminated by washing in frequent changes of water, or, better still, in running water. To test when this is complete, a piece of blue litmus-paper should be pressed against the wet cotton, and if after two minutes it remains unaltered it may be assumed that the washing is complete. The pyroxyline should now tear easily, and not be readily separable into the original balls, and should weigh about 30 grammes. If the original fibre be easily distinguishable, the temperature probably fell during the operation, or sufficient water was

[1] The cotton should have previously been well steeped in soda and water, and be then *thoroughly* washed and *completely* dried.

[2] If the precaution be not taken of squeezing out the acids, there is a great probability of a solution of a portion of the cotton taking place.

not added. If the weight fall much below that indicated, the water was probably a little in excess, or the temperature was too great. It cannot be too strongly impressed upon the student that the strength of acids is all-important, and if the amount of water present with them be above that indicated, that so much water must be deducted from that given in the formula. A specific gravity bottle is a very convenient means of ascertaining the strength of the solution, for, the specific gravity once known, the amount of true acid present can be found from the tables given in the appendix Other methods for ascertaining the specific gravity will be found in most works on Chemistry.

The next formula for preparing pyroxyline of the same character is given without comment, as the above remarks apply to it.

Sulphuric acid, 1·842	170 cc.
Dried potassium nitrate[1]	110 grammes
Water	28·3 cc.
Best dried cotton wool	4 grammes.

Hardwich states that the chances of failure with this process are very slight if the potassium nitrate be not too much contaminated with potassium chloride. In the above operations a thermometer is absolutely necessary. It should not be mounted in wood, but should be graduated on the stem itself. It may be supported in a clamp, as shown in the figure. For dry processes the foregoing formulæ give pyroxyline, which some consider as too tough and horny, and some hold, though the writer does not, that this is especially the case for processes where the sensitive salt of silver is formed in the collodion itself (see chap. xvi.). A modification in the proportions of acid and water can be made to suit those who prefer a more limpid collodion. It has also been found by some workers that in the latter process the presence of a little nitro-glucose is a desideratum.

[1] The potassium nitrate should be dried at a temperature of about 120°. Placing it in an air-bath is the most convenient method of obtaining the temperature.

The following method secures its formation, though, if the resulting pyroxyline be well washed, it is in a great measure eliminated. It would seem better to add the nitro-glucose to the collodion, but as this has not been established from long experience, it has been thought better to give the process as published by M. Leon Warnerke, in a communication to the Photographic Society of Great Britain. Six grammes of the finest cotton-wool are put into a porcelain jar, and 2 grammes of gelatine dissolved in the smallest quantity

FIG. 9.

of water are added. The cotton is impregnated with the gelatine by pressing it with a wooden spatula, and when this is effected the cotton is carefully dried by the aid of heat. It is then ready for immersion in acids which are of the following strength :—

Nitric acid, 1·45	175 cc.
Water	68·3 cc.
Sulphuric acid, 1·840	262·5 cc.

Or,

Nitric acid, 1·42	194·1 cc.
Water	49·2 cc.
Sulphuric acid, 1·840	262·5 cc.

The acids and water are mixed in the order named, and when a steady temperature of 70° is obtained the gelatinised cotton is immersed in it for twenty minutes. With some cotton the amount of water given above is inadmissible, as it immediately dissolves. The proportions of acids should be kept, and the water diminished to such a degree that the solvent action is reduced. After washing and drying, the resulting pyroxyline will be found to have lost considerably in weight, and it should be almost powdery in appearance, and readily disintegrable. It will be found highly soluble in a mixture of ether and alcohol, and as much as 2 per cent. may be required to give a sufficient body to the collodion.

Hitherto cotton has alone been mentioned as capable of forming pyroxyline; but it may be stated that every analogous substance may be similarly treated. Thus linen and paper are amenable to the above treatment, and for some purposes they give superior results; for instance, Whatman's drawing paper has been found by Warnerke to give better results than the gelatinised cotton in the last process. Being already sized with gelatine, there is no need for the preliminary treatment pointed out.

The action of the solvents employed in the collodion on the pyroxyline deserves a passing remark, as many modifications in the resulting film can be caused by judiciously varying their proportions. The specific gravity of the alcohol employed should invariably be ascertained, as the condition of the sensitiveness of the plate depends much upon its strength. With a collodion made at a low temperature, the presence of a certain percentage of water is advisable, as its horny nature is thereby modified, and a certain degree of porosity obtained. A specific gravity of ·820 is in this case admissible. With the pyroxyline such as that obtained by the last formula, the water should be a minimum, as it is already porous, and the presence of water is apt to make it reticulated and rotten. The specific gravity in this case should rarely be over ·812. An excess of alcohol

also tends to give porosity, and therefore sensitiveness; but if the addition be carried to an extreme, the very porosity diminishes sensitiveness, as the sensitive salts formed in the film coagulate into too large particles. Alcohol also diminishes the rapidity of setting. Ether, on the other hand, tends to close the pores of the film, as is demonstrated by coating a plate made with an excess of it, when it will be found that a contraction takes place, causing the film to leave the edges of the plate, or to split on drying. The ether employed should be as pure as possible (this is not insisted on by manufacturers of collodion) as otherwise it is apt to liberate the halogen from the dissolved salts, giving rise to an alkaline reaction which is one cause of rottenness in the film, and an apparent want of body in collodion.[1]

The following are collodions for different processes.

For the wet process:—

No. 1.	Pyroxyline, Hardwick's formula . .	12 to 14 grammes
	Alcohol, ·820	450 cc.
	Ether, ·725	550 cc.
No. 2.	Pyroxyline, Hardwick's formula . .	12 to 14 grammes
	Alcohol, ·820	500 cc.
	Ether, ·725	500 cc.

No. 1 is most suitable for cold, and No. 2 for warm weather.

For dry processes with the bath :—

No. 3.	Pyroxyline, first formula . . .	10 to 12 grammes
	Pyroxyline, last formula . . .	4 grammes
	Alcohol, ·813 or ·814. . . .	500 cc.
	Ether ·725	500 cc.
	Water	Quant. suff.

The water is shown in No. 3 to remind the student it puts a power into his hand of modifying the collodion in structure by its addition. It frequently happens that No. 1 or 2

[1] The student would do well to try the experiment of adding a small quantity of caustic potash to a phial of collodion, and noting the action that takes place.

formula may also be improved for dry processes by attending to the amount of water present.

The next point to be determined is the amount of bromide and iodide to be dissolved in the collodion, and to determine their proportions it will be well to enter into detail as to their behaviour when converted into the silver compounds and exposed to the light. Iodide of silver in a film is capable of forming a dense image with a short exposure, but the gradations in density are often wanting when the light is extremely bright; added to which, if organic matter be present with it even such as is to be found in many collodions, the picture is apt to be veiled and wanting in vigour.

Bromide of silver, on the other hand, is especially adapted for those collodions which have an organic reaction. It has usually been accepted that the iodide is the more sensitive of the two salts, but recent investigations tend to show that, with suitable development, the bromide has the advantage, when developed by Method 3 (p. 19). It does not yield such a dense image, but the detail in the denser parts is always present. The failing of the bromide consists rather in its comparative insensitiveness to very faint light as found in deep shadows. A bromo iodide of silver, however, combines the advantages of the bromide with that of the iodide; for the wet process and certain of the dry processes, it possesses every essential quality for the production of a good picture. The proportions of bromine and iodine in combination vary considerably, from 1 part of the former to 10 parts of the latter (which is just sufficient to secure cleanliness and freedom from veil with all ordinary preparations of collodion and bath) to 3 parts to 2. The latter proportion is never employed except in dry-plate processes. The iodide is usually fixed at about from 6 to 10 grammes per litre. The sensitiveness of the surface in all cases depends on the mode of development employed. Thus for a wet plate, Vogel has found that

the proportion of iodine to bromine should be about 4 to 1 to secure the greatest sensitiveness, whilst with the alkaline method it is diminished to the smaller proportion. It may also be said that the proportion of bromine to iodine which gives a clean image in working with the wet method is the same as that of iodine to bromine required for working the dry process. The metal with which the iodine and bromine are combined when introduced into the collodion, serves to exercise a great influence on the sensitiveness of the surface. Quite recently Warnerke has stated that the metals combine with the pyroxyline and form compounds, whose composition is as yet undetermined, and thus the difference in structural effect and viscosity exhibited between two identically similar collodions when iodised with a cadmium and an alkaline salt may be accounted for in a great measure. For experiment, it will be advantageous if the student iodise two portions of collodion ; one with 4 grains of cadmium iodide, and the other with 4 grains of potassium iodide, and note the difference in their behaviour when poured on a plate. With the latter he will find a freely flowing fluid; with the former one which is more glutinous, and difficult to manipulate.

It also appears that the different metallic salts in solution cause different degrees of sensitiveness in a film. This has been investigated by Warnerke, who places them in the following order for imparting sensitiveness and intensity:—

Order of sensitiveness . . .	Zn	Cd	Na	Fe	NH_4	K	U
Order of intensity of image .	Zn	U	NH_4	Cd	Na	K	Fe

The alkaline iodides are those which are most prone to decompose under the action of ether, particularly if it be methylated, hence, for a collodion to keep long, it is necessary that the purest form be employed. As before shown, when the iodide is decomposed, the alkali decomposes the pyroxyline, rendering it very fluid and defective in setting

qualities, whilst the iodine itself increases the density of the image, probably by the formation of a silver iodate.

In bromised collodion it is very rare for bromine to be set free, and in bromo-iodised collodion the dark colour obtained by long keeping is invariably due to the iodine liberated, for *uncombined* bromine will always displace iodine. To increase the density of a developed image it is always advisable to add a little tincture of iodine to a collodion.

In choosing the iodide or bromide of any particular metal for iodising or bromising a collodion, it must be remembered that it is the amount of iodine and bromine that are the essentials, and not the metal. Hence, 4 grains of ammonium iodide and 4 grains of cadmium iodide mean a totally different quantity of iodine. A table of these quantities will be found in the appendix.

The following formulæ will be found to give collodion suitable for the ordinary wet process:—

No. 1.	Ammonium iodide	7 grammes
	Cadmium bromide	4 grammes
	Plain collodion[1]	1 litre.
No. 2.	Ammonium iodide	8 grammes
	Cadmium bromide	2·5 grammes
	Plain collodion	1 litre.
No. 3.	Cadmium iodide	9 grammes
	Cadmium bromide	4 grammes
	Plain collodion	1 litre.

Nos. 1 and 2 are speedily ripe enough for use; with a little alcoholic tincture of iodine added they may be employed immediately.

No. 3 requires keeping, as at first it will not flow freely. A sample of collodion such as No. 3 has been kept two years without deterioration, the precaution being taken to keep it in the dark and in a cool place.

[1] It must be borne in mind that the collodion may be made by 1, 2, or 3 formula, and the pyroxyline may be of the varying types shown at p. 50. Formula No. 2 is that usually to be recommended.

No. 2 is suitable for dry-plate work and for interiors, but as a staple article No. 1 is recommended.

For a simple iodised collodion the following formula may be adopted:—

No. 4.	Ammonium iodide	8 grammes
	Plain collodion	1 litre

Or,

No. 5.	Cadmium iodide	10 grammes
	Plain collodion	1 litre

No. 4 should be used immediately after making, whilst No. 5 will keep almost indefinitely.

The next formula is for a simple bromised collodion:—

No. 6.	Zinc bromide	16 grammes
	Plain collodion	1 litre

For all the above iodides and bromide substitution may be made with others, and it by no means follows that those chosen as examples will prove the most sensitive, though experience has shown they give good results. It is customary in preparing plain collodion to omit half of the alcohol, and to employ that half as a solvent for the haloid salts. This is convenient but not absolutely necessary. It is a good plan to make a note of the date of the manufacture of the collodion, as also of its iodising; useful information is often given by such memoranda.

Testing Plain Collodions.

Plain collodion should be tested before iodising, and the following tests may be applied, recollecting that a film that may not be suitable for the bath process may still be suitable for an emulsion process, and *vice versa.*

Coat a plate (in the manner described at p. 79), and ascertain if when dry the film dry dead white, opalescent, or transparent. If the first, it is unsuitable for any process; if the second, it may be employed for emulsion work; whilst if the third, it may be suitable for any process.

Coat a plate, and, after the collodion has set, mark if it

is powdery to the touch, or if on applying the finger it comes away in strips. If the former, it may be good for dry-plate work; if the latter, for both dry plates or the wet process.

Coat another plate, and, after setting, wash the film under the tap till all the solvents are washed out, and note if it take an even film of water or if it repels it at parts. If the latter it is too horny to use in the bath processes; a little potassium carbonate may improve it.

Note if the collodion flows freely, viscously, or lumpily. Too limpid a collodion will fail to give density; too viscous a collodion is unsuitable for any but small plates, whilst a lumpy collodion will give irregular images. The flowing qualities of a collodion arising from the pyroxyline may often be corrected by altering the proportions of ether and alcohol.

If the film be reticulated, having marks like a crape pattern on it, the solvents may not be sufficiently anhydrous, or the pyroxyline may be in fault, as before stated.

The collodion should also be tested after iodising; the defects will be noticed when treating of the defects in negatives produced by the various processes.

CHAPTER VIII.

CLEANING THE GLASS PLATE.

The plate, before being taken into use, should be most carefully cleansed from dirt of any description. The success of a photographer may be said to depend in a great measure on the effectual manner in which he completes this operation. The dirt that is to be looked for on a glass plate is that due to the manufacture, that due to subsequent exposure to the atmosphere and to the hands of the packers,

and sometimes that due to the chemical compounds with which it may have been in contact. Ordinary plates are sometimes found to be gritty on what should be the polished surface, and the application of acid may dissolve the grits away. Hence it is a good plan to treat all new plates with a solution of dilute nitric acid (10 parts of water to 1 of acid). This will not rid them of mechanical dirt, such as dust or grease. The presence of dust is readily accounted for, but the origin of the greasy matter is far more difficult to understand. If a plate that is thoroughly cleaned be put away in a plate box for a few days, and be then examined by breathing on it, it will be found that it shows signs of repelling the aqueous vapour from the breath in certain parts, and that a subsequent cleaning of the plate is necessary to render it fit for use. This phenomenon can be accounted for on the supposition that organic matter of a fatty nature is to be found in the atmosphere, and when we remember that the lungs expire not only carbon dioxide, but also various organic matters, we should expect that in an inhabited house this latter might condense on some dry cool surface. The danger of using plates on which this deposit exists will be apparent by a simple experiment. Rub a warm finger or hand over the plate, coat with collodion, sensitise, but do not expose to light; then apply the developing solution and watch the result. It will be found that where the contact has been made, a reduction of metallic silver will take place, and as development proceeds a dark stain will be produced. Imagine a similarly treated plate, prepared as before, exposed in the camera and developed; a dark deposit will take place both where the hand has touched and also where the invisible image has been impressed. It may be said that all animal organic matter has the property of causing a tendency for metallic silver to be reduced from the solutions of its salts. A similar remark applies to the mercury compounds which sometimes get invisibly reduced in the surface of the glass. The composi-

tion of dust is of a most varied nature, and not unfrequently consists of ferric oxide, sodium chloride, and other earthy constituents. The reduction of silver nitrate in the presence of some of these would be certain.

Alkalis have the property of converting greasy into saponaceous matter, and spirits of wine will dissolve both soap and grease; hence both are employed as detergents. Mechanical dirt requires friction to remove it, and this should be just sufficient for the purpose, yet not enough to injure the surface of the glass. Such bodies we have in tripoli powder and rouge. The former is recommended on account of its being less gritty than the latter. The most common cleaning solution is made as follows :—

Spirits of wine	50 cc.
Tripoli powder :—Quantity sufficient to make a thin cream	
Ammonium hydrate.	1 cc.

Mr. Warren De la Rue for his astronomical photography employed a solution of potassium dichromate and sulphuric acid. This is doubtless a most effective detergent, but the use of sulphuric acid is open to objection on account of the damage it may do to the dress or hands.

The writer has heard of a process of cleaning recommended, in which it was proposed to employ potassium cyanide, followed by nitric acid. The student is earnestly recommended not to attempt this plan, as it is poisonous and highly dangerous (see p. 74).

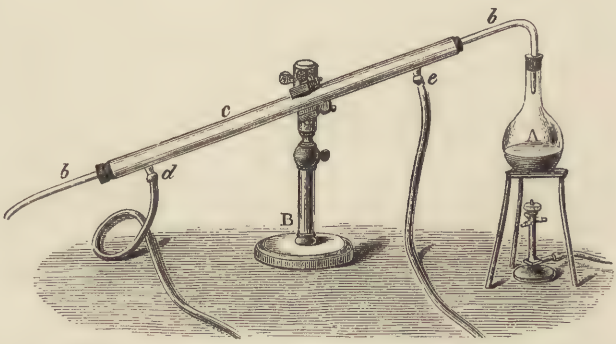
Boiling the glass plate in caustic soda or potash has also been proposed. This is apt to injure the surface of the plate, owing to the slight solubility of vitreous matter in solutions of the caustic alkalis. Perhaps no more effective method for securing a clean plate can be adopted than by first treating the plate with a cold solution of caustic potash, rubbing it well in with a rag, and then immersing it in dilute nitric acid and washing under the tap. A final thorough rinse in distilled water, and a rapid drying in a

water-oven, will leave the plate in as clean a state as can be desired.

SENSITISING BATH.

The sensitising solution, that is, the solution in which the collodion containing the soluble iodides or bromides, or both, are immersed in order to form the iodide bromide, or bromo-iodide of silver, may be said to be invariably made of silver nitrate dissolved in water. The purity of both constituents is of the highest importance, as any extraneous matter may be fatal to obtaining good results in development. Distilled water is naturally the purest form of water that can be obtained, but even this is sometimes contaminated with organic matter in solution, which is apt to react upon the sensitive salt. The manner in which am-

FIG. 10.



monia is carried over with the aqueous vapour is well known to any chemist, and in a similar way hydrogen sulphide can be carried over. The latter contamination is most hurtful to sensitiveness, and the former might cause fog. It may be useful to point out the best mode of distilling water in a small way, in order to obtain absolute purity.

A glass retort is always clean, and dirt can be more

readily seen than if it be of metal. The form known as Liebig's condenser is therefore recommended instead of the ordinary still. The water should be placed to the level of the flask A shown in the diagram, and a little (say a gramme to a litre) caustic potash should be dissolved in it. This will free the water of any ammoniacal compounds when warmed. The distillation takes place through the glass tube, *b*, round which is placed a glass jacket, *c*, containing water. Cold water is allowed to enter the jacket by the tube, *d*, and the heated water is carried off by *e*; an universal clamp, B, is useful for holding the condensing apparatus in position.

The first 50 cc. of each litre distilled should be rejected, and the distillation should not be continued beyond that point where 100 cc. are left in the retort. The distillate may then be considered to be pure enough for photographic purposes. If an ordinary worm still be employed, care should be taken that the worm is clean, free from dust, and not of lead. The water should be distilled over as before, the first and last portions being rejected. If distilled water cannot be obtained for making up the solution, spring water, if not impregnated with sulphates, will generally answer. Failing these, river water, and lastly rain water, after twice filtering through charcoal, must be resorted to. At first it may seem strange to place rain water last on the list, but it should be remembered that it is almost invariably collected from the roofs of houses, and is consequently sure to be contaminated with organic matter, and also inorganic matter. Rain water, if it could be collected directly as it falls, would save the necessity for using distilled water. A method of purifying ordinary water for bath purposes is as follows. Boil and filter it, add a little barium nitrate to it, and see if it turns milky. If such be the case, add a small further quantity, together with a few crystals of silver nitrate to each litre of water, and place in the sunlight. After a few hours' exposure, the organic

matter and sulphates will be at the bottom of the containing vessel, and the supernatant water may be decanted, syphoned, or filtered off. An excess of barium nitrate is not hurtful to the solution, for, as will be seen at p. 62, its addition is recommended.

Nitrate of silver should be pure. The uncrystallised will be found sufficiently free from nitric acid to be available for forming a bath solution needing no doctoring. It is sometimes adulterated; if any suspicion of this arise, a certain known quantity of the crystals should be dissolved up in water, and the amount of silver nitrate really present calculated by any of the methods usually adopted. Silver nitrate is readily soluble in its own weight of water, but this strength would be quite unsuitable for a sensitising solution for two reasons: first, silver iodide is soluble to a certain extent in silver nitrate solution. The stronger the latter, the greater the amount of iodide dissolved. A variation in temperature also affects the quantity capable of being held in solution. Now, even supposing that at the temperature at which the bath was formed immersion of an iodised plate took place, the heat evolved in the act of combination between the soluble iodide and the silver nitrate to form the sensitive compound would be sufficient to cause the iodide in the film to be partially dissolved out. Secondly, the formation of the iodide would be so rapid that there would be a coarseness in the particles unsuitable for rapidity. Sutton has demonstrated that where any iodide is in the solution, 10 per cent. is as great a strength as can well be managed, whilst a 5 per cent. solution is the limit in the other direction. When bromides alone are employed, the strength may be 15 per cent., as the silver bromide is almost insoluble in silver nitrate solution.

In preparing a bath it is generally saturated with silver iodide, to prevent the silver nitrate dissolving away portions of the sensitive surface. Some skilled photographers, however, prefer the saturation to take place from the film

itself, a method which is recommened to the student, if he exercise ordinary care in working his plate. The degree of acidity of the bath depends much on the iodising or bromising of the collodion. To secure the greatest degree of sensitiveness, if iodide alone be present the solution should only be faintly acid, with bromo-iodide it should be distinctly acid, whilst with bromides alone it should be very acid. The rationale of the different degrees of acidity is as yet not known accurately, more investigation into the subject being required; but it may be presumed that it is in a measure dependent on the behaviour of the silver bromide and iodide when exposed in the presence of silver nitrate.

The following formula for the silver-bath solution is a standard one where iodide or bromo-iodide of silver is the sensitive salt to be produced:—

Recrystallised silver nitrate . .	80 grammes
Water	1 litre
Potassium iodide	·25 gramme

The silver salt should be dissolved in a quarter of the water, and the potassium iodide added to it after solution in the least possible quantity of water. After shaking (which will cause a partial solution of the silver iodide first formed), the remaining water should be added, when a further emulsion of iodide will appear. When filtered out, the bath solution will be ready for use, supposing proper acidity to be attained.

An excess of acidity may be corrected by the addition of a few drops of a sodium carbonate solution. When a permanent precipitate is obtained, the requisite acidity should be given *after filtering* by adding a few drops of a 5 per cent. solution of nitric acid. Some photographers have recommended the employment of acetic acid instead of nitric acid, but the writer has never found any benefit resulting from it—in fact the reverse; for although acetic acid added to silver nitrate will not at first form silver acetate, yet as the solution becomes contaminated by working

there is danger of compounds forming, which will combine with it, and finally cause decomposition between the new compound and the silver salt.

As the bath solution gets worked, that is, has many plates immersed in it, the original purity becomes impaired by the accession of ether, alcohol, and various nitrates from the collodion, besides any extraneous matter that may accidentally be carried in. After a time the vigour and cleanliness of the developed image will be found to diminish, and the strength, &c., of the bath has to be attended to. Gently warming it will get rid of the ether, and evaporating it to half its bulk will get rid of most of the alcohol. If organic matter be present, exposure of the bath (after neutralisation of the free acid with sodium carbonate) will cause metallic silver to be precipitated, and itself to be oxidised by the liberated molecule of nitric acid, thus rendering it innocuous.

With certain collodions acetic acid will find its way into the bath, and the best method of eliminating the silver acetates which will probably have been formed is to evaporate the bath to dryness and add some strong nitric acid. This will liberate the acetic acid, which may be driven off by a further application of heat. None of these modes of treatment will eliminate all the impurities, for all the foreign nitrates (except ammonium) remain almost unchanged, even by prolonged fusion ; nothing remains but to precipitate the silver as chloride, or in the metallic state. If a film, after withdrawal from the bath, presents an appearance as if fine particles of the sensitive salt had been sprinkled over it, the solution is 'over-iodized' ; that is, it is super-saturated with silver iodide. The disturbance made by the immersion of the plate probably causes the deposit. Diluting to double its bulk, next filtering, and then making up the solution to proper strength, will be a cure, or, as some photographers aver, the addition of 2 per cent. of barium nitrate will answer the same end.

CHAPTER IX.

DEVELOPMENT OF THE PHOTOGRAPHIC IMAGE.

THE importance of a thorough understanding of the rationale of developing an image in the silver compounds is not to be over-rated, as a close study of it furnishes clues to apparently mysterious results, which are so often met with by every student in the art. The method of developing the Daguerrean image has been already given, and we propose in this chapter to confine ourselves to that employed in what is known as wet-plate photography and dry-plate photography, and also that followed in the calotype and other kindred processes.

It will be recollected that by method 1 the invisible image was to be made visible by the attraction exercised by the new compound formed after the impact of light on the original one. As already announced in chap. iv. p. 24, the change effected on a molecule of silver haloid is its reduction to a lower type, *i.e.* one containing a lesser number of atoms. Thus Ag_2I_2 was reduced under certain circumstances to Ag_2I, the other atom of iodine being absorbed by some body in contact with it. A similar change was shown to be effected on the silver bromide and chloride. We may, therefore, take as a type any one of these. We will choose the iodide, and follow the development from the earliest stage, when used in the wet process.

It has already been shown at p. 19 that the building up of the image is due to the well-recognised law that every minute freshly-formed crystal attracts every other of a similar nature, and that the formation of the tree is entirely due to this molecular attraction, and the slow reduction of the metal from its solution. If the metal were deposited rapidly the

same law would still hold good, but the attraction of one reduced molecule on its immediate neighbour would be greater than that exercised by the metal adhering to the rod, as the probable distances in the one case would be far less than in the other. A particle of such a size and weight would therefore be built up before the metal on the rod could draw it sufficiently near to overcome the force of gravity exercised on it; hence it would sink to the bottom of the containing vessel.

If we take a solution of silver nitrate and add to it a solution of ferrous sulphate, we have an almost instantaneous reduction of metallic silver. Thus—

$$\begin{array}{ccccccc} \text{Silver nitrate} & + & \text{Ferrous sulphate} & = & \text{Silver} & + & \text{Ferric sulphate} \\ 3\ AgNO_3 & + & 3\ FeSO_4 & = & 3\ Ag & + & Fe_2(SO_4)_3 \\ & & & & + \text{ Ferric nitrate} & & \\ & & & & + \quad Fe(NO_3)_3 & & \end{array}$$

Any other oxygen-absorbing medium which is incapable of causing double decomposition with the silver nitrate might be substituted for the ferrous sulphate. By adding an acid to the latter the same action takes place, but much more slowly, the time necessary to effect the total reduction being dependent on the amount of acid present. Supposing by some means or another we are able to cause the first crystals of the silver to deposit themselves in certain positions, we may be certain from analogy that the remaining crystals will adhere to these and build up a miniature silver tree. In the wet process, and also in the dry, we have means of causing these first particles of silver to deposit on the invisible image.

This invisible image is formed of subiodide of silver (Ag_2I). Only one of these atoms of silver is saturated; the other is still ready to combine with any other atom with which it has an affinity. Such an atom it finds in freshly-deposited silver. The solution of silver nitrate is already present in the wet process, and in the dry processes it is

added to the oxygen-absorbing agent, which is employed in both.

The first deposited crystals attract others, and thus an image is built up. It may, however, be asked how it is that different density of deposit is caused. The answer to this is that the invisible image is formed of variable quantities of the subiodide, approximately proportional in fact to the intensity of light acting on it. At any spot on the sensitive surface it is the integral of the attractions of the different atoms lying close to one another that determines the amount of the first deposit, and the varying mass of this determines the distribution of the subsequent deposit.

It is an axiom that the stronger the solution of the reducing agent the more rapid must be the deposit, and it may be convenient here to discuss the bearing of this. Suppose adjacent particles of the sensitive surface possess separate attractions of, say, 1, 2, 3, and 4 units, caused by the different intensities of light acting on those parts. The probabilities are that the first metallic silver atom deposited will be drawn to the spot possessing 4 units of attraction. If the interval in time for the reduction of the next atoms exceed that necessary for placing the first atoms *in situ*, the attraction originally equal to 4 units will become approximately 5, and the probabilities are that the larger proportion of the next reduced atoms will be attracted by the 5 units than by the 3; and by the same action the 4 units may attract several atoms, whilst the 3, 2, and 1 units may have attracted proportionally less. If the reduction of a sufficient number of atoms to saturate the whole of the atoms of Ag_2I take place almost simultaneously, the probability is that the difference in the increase of attractive power will be less marked. Thus 4 may become 5; 3, 4; 2, 3; and 1 become 2. It may therefore be asserted that the position of the first deposition will determine that subsequently taking place, provided the same rate of the reduction be maintained. From the foregoing reasoning it will be

apparent that the stronger the developing solution the less marked will be the variation in density due to the different intensity of light acting on the various portions of the sensitive salt.

The more viscid a liquid and the smaller the mass of the particle, the slower will a particle travel through the liquid. An application of this law has been applied to development. A certain amount of colloidal substances, such as gelatine, albumen, or these bodies acted upon by acids, is added to the liquid in which the oxygen-absorbing agent is dissolved. Though the reduction of the silver nitrate to the metallic state, may take place as rapidly as in a solution in which the colloidal body is omitted, yet the time the metallic atoms take to travel through the viscous solution is lengthened to such an extent that an appreciable time is taken to form a visible particle of silver. The time, therefore, taken to build up an image is longer than with a solution in which the colloidal substance is absent; it is found that a small quantity of the colloid will give sufficient viscidity to cause slow deposition. The examination under the microscope of an image developed in the manner indicated above will perhaps throw more light on the subject than any verbal description that can be given. It will be found that the whole of the image is formed of these minute crystals, varying in size according to the length of time which they took to deposit. The appearance of the film when the half-tones of the negative are thus examined, will be as though it had been sprinkled with the metallic granules by means of a pepper-box; whilst the parts representing deep shadows will be represented by large patches of bare collodion, with here and there a crystal lying embedded in the film. The student should take every opportunity of studying the effect of different kinds of development as regards the actual physical composition of the image; and he may rest assured that the highest excellence in any negative can never be attained when the deposit is coarse and highly crystalline. With a 2-inch objective it should appear as a stain on the film of more or less intensity.

The following are the formulæ usually employed in development :—

No. 1.	Pyrogallic acid	1 gramme
	Glacial acetic acid	20 cc.
	Alcohol	Quant. suf.
	Water	500 cc.

This developing solution is usually employed for simply iodised collodion, and is useful when great density in the lights is required. The iron developers of a weak and strong type are as follows :—

No. 2.	Ferrous sulphate	10 grammes
	Glacial acetic acid	30 to 40 cc.
	Alcohol	Quant. suf.
	Water	1 litre
No. 3.	Ferrous sulphate	100 grammes
	Glacial acetic acid	40 cc.
	Alcohol	Quant. suf.
	Water	1 litre

These formulæ give the limiting proportions of ferrous sulphate to water admissible, but any quantity between the two may be taken. For ordinary work, about 40 grammes is usually taken, as giving the best results. The double sulphate of ammonium and iron may also be substituted for the ferrous sulphate, and it has the advantage of remaining in solution unchanged for a long period.

The addition of copper sulphate to an extent equal to half the quantity of ferrous sulphate employed is also recommended by some operators, and it has doubtless in some cases a beneficial effect.

The addition of various colloidal substances to the developers, as already stated, may sometimes be desirable, particularly where great density and fine deposit are requisite. Perhaps the best of any is that proposed by Mr. Carey Lea: it is made as follows:—30 grammes of French glue, or gelatine, is softened in 50 cc. of water, to which $3\frac{1}{2}$ cc. of sulphuric acid is added. The water is next boiled, and the

gelatine dissolves, and, after adding another 10 cc. of water, the boiling is continued for a couple of hours. Five grammes of metallic zinc are next added, and the boiling continued one hour and a half longer. The solution is allowed to settle, and the clear liquid decanted off. To every 3 grammes of ferrous sulphate, 1 to 2 drops of this solution suffices to give sufficient restraint, without the addition of any acetic or other acid.

Ferrous sulphate is a very unstable body, and will absorb oxygen from the air, and speedily attain the ferric state ; and as the latter salt is incapable of absorbing more oxygen, it is evident that the developing qualities are thus annihilated. It has been in effect found that ferric sulphate is a retarder, that is, a body which prevents the rapid deposition of the metallic silver from the nitrate solution. The lesson to be learnt from this is, that when the developer attains a red colour it must of necessity be slower in action than when of the ordinary apple-green tint. A simple experiment with a developer containing ferric sulphate is worthy of trial by the student. Take, say 3 grammes of ferrous sulphate, and having dissolved it in 50 cc. of water, boil with strong nitric acid to such an extent that the addition of a drop of the solution to one of potassium ferricyanide produces no blue precipitate. Next precipitate the iron as ferric oxide by ammonia, filter, wash well, and dissolve up in the least possible quantity of sulphuric acid, taking care to leave a slight residue undissolved. Make up the quantity of liquid to 10 cc., and add 2 cc. to a solution of ferrous sulphate made according to formula No. 3, omitting the glacial acetic acid. Develop a picture with it, and note the result.

Attention should be paid in all cases to the crystals of ferrous sulphate employed. They are frequently mixed with a yellowish powder, due to the decomposition of the salt. In common specimens this often bears a considerable proportion to the ferrous salt itself, and must be allowed for in making up the solutions. The strength of the acetic acid is also

important. What is commonly sold as glacial is often below strength. Its value should be estimated as given in various works on chemistry. In warm weather, owing to the increased rapidity of chemical action, more acetic acid is required to control the reduction of the silver nitrate. Hence these quantities shown may require modification according to the temperature.

The amount of alcohol required is invariably shown as 'quant. suf.' No definite quantity could be given, as it varies according to the amount of alcohol present in the bath solution. With a new bath none at all is required, whilst with one in which a large number of plates have been sensitised as much as 40 cc. to the litre may be necessary. A deficiency or excess of the alcohol is shown by the solution refusing to flow evenly over the surface of the sensitised collodion, and running into rivulets and tears. This is caused by the difference in surface tension of the fluid on the plate and the developer. Any body which reduces the deficiency may take the place of the alcohol. Thus a more viscid solution, such as that given by the gelatine retarder, is effective, no alcohol being required with it, even when the bath is very old. Methylated alcohol[1] should be avoided as far as possible, stains and disfigurements in the developed image being often attributable to it.

CHAPTER X.

GIVING INTENSITY TO THE IMAGE.

Any method of increasing the apparent depth or blackness of the image when received by reflected light, or of increasing the opacity of the image to non-actinic, or to

[1] Spirits of wine, sold as methylated, sometimes contains a certain quantity of resinous substance, in order to satisfy the excise requirements.

visual rays, is termed intensifying the image, and in both cases the result can be brought about by the same procedure. The following are modes of giving intensity to the image.

1st. We may continue the development of the image by method 1, if we supply more free silver nitrate solution to it when exhausted ; and this will give us the necessary intensity. The theoretical considerations before noted need not be again brought before the student, neither is any special experiment necessary to impress them on his mind.

2nd. We may produce opacity to actinic rays by increasing the deposit by other means. As an example of what is meant, we may apply to the silver image a solution of mercuric chloride.

$$\begin{array}{ccccc} \text{Mercuric chloride} & + & \text{Silver} & = & \text{Double chloride of mercury and silver} \\ HgCl_2 & + & Ag & = & AgHgCl_2. \end{array}$$

This at first is grey (probably due to the formation at first of silver subchloride), but it finally becomes a pure white. It will be noticed that each atom of silver attracts one atom of $HgCl_2$. As regards opacity without regard to colour, the image must evidently be more opaque. It is, however, as regards actinic rays much less opaque than when the image was of the grey due to the silver.

An application of ammonium hydrate to it, however, converts it into a jet black or deep brown.

Here we have a still further deposition on the silver atom, which is therefore denser, and, being black, is very opaque to actinic rays.

As another example of this mode of intensification we may instance the effect of copper bromide on metallic silver, and the subsequent treatment of the deposit thus formed with silver nitrate.[1]

$$\begin{array}{ccccccc} \text{Silver forming the image} & + & \text{Copper bromide} & = & \text{Silver bromide} & + & \text{Copper sub-bromide} \\ Ag & + & CuBr_2 & = & AgBr & + & CuBr \end{array}$$

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[1] For a detailed account see *Photographic Journal*, April 1877.

When treated with silver nitrate we have—

Silver bromide	+	Copper sub-bromide	+	Silver nitrate	=	Silver bromide	+	Silver sub-bromide	+	Copper nitrate in solution
$AgBr$	+	$CuBr_2$	+	$2AgNo_3$	=	$AgBr$	+	Ag_2Br	+	$Cu(NO_3)_2$

It will be seen how immensely the deposit on the image is increased by this method.

Lastly, intensity in an image may be secured by substituting some other metal for the silver by chemical means. For example, we may apply a solution of platinum tetrachloride; the silver will be converted into chloride, and the platinum will be deposited in its place. The silver chloride may be subsequently dissolved away by sodium hyposulphite or ammonia, or by many of its well-known solvents.

From a study of these methods it will be apparent that methods 2 and 3 must each be carried out on an image from which everything else is removed but the metallic silver; method 1 may be employed without such removal.

The formulæ for the first method are as follows:—

No. 1.	Pyrogallic acid	4 grammes
	Citric acid	4 to 8 grammes
	Water	1 litre
No. 2.	Ferrous sulphate	10 grammes
	Citric acid	20 grammes
	Water	1 litre

With the latter intensifying solution detail in the shadows is often brought out, though absent in the development, but the former is the most efficacious for rapidly giving opacity to the image. With each of the above a few drops of a solution of

Silver nitrate	20 grammes
Water	500 cc.

must be added immediately before application to the film. These intensifying solutions may be applied to the image either before or after fixing; those which follow, however,

require the unaltered iodides and bromides to be previously dissolved away.

Iodine	·1 gramme
Potassium iodide	·2 gramme
Water	50 cc.

The iodine (which is held in solution by the help of the potassium iodide) converts a portion of the reduced metallic silver into iodide, and when continued but for a short time the image has a bluish-green tint, which is more non-actinic than if it were left in the metallic state. If this be not sufficient a solution of

Potassium permanganate . . .	1·5 gramme
Water	50 cc.

may be flooded over it. The permanganate is decomposed in coming in contact with the silver iodide, and insoluble manganic oxide is precipitated on the image.

Another form of intensifier is made by—

Mercuric chloride	·2 gramme
Water	750 cc.

and,

Potassium iodide	1 gramme
Water	50 cc.

The latter is added to the former till the red precipitate of mercuric iodide is on the point of becoming permanent. This solution applied to the image converts the silver into double iodide of mercury and silver, which is very non-actinic in character; other similar methods may be adopted, all depending on the formation of double metallic compounds. By converting the silver image into iodide by the application of the iodine solution, and then flooding with sodium sulph-antimoniate (Na_2S, SbS_5) commonly known as Schlippe's salts, a scarlet deposit is produced of silver sulph-antimoniate in which 2 atoms of silver replace the 2 atoms of sodium, the iodine combining with the sodium. This method of intensification is due to Carey

Lea, who described it in a paper which appeared in Feb. 1865, in the American 'Journal of Photography.' Schlippe's salts are prepared by taking

Antimony bisulphide (finely powdered)	18 parts
Dried sodium carbonate . . .	12 parts
Caustic soda	13 parts
Sulphur	3½ parts

These are ground up into a fine paste with a little water, and transferred to a well-closed stopped bottle, completely filled with water. After digestion and agitation for twenty-four hours, the clear liquid is filtered off, and allowed to evaporate spontaneously in a closed vessel over sulphuric acid, till lemon-coloured crystals of a regular tetrahedral shape are obtained. These are dissolved in water immediately before use, as the solution deposits an antimony compound when kept. The mother liquor may be employed for intensifying, but does not answer so well as the salt itself. The quality of the colour is dependent on the amount of silver converted into iodide or chloride.

When great density is required without gradation of shade, the following formula is efficient when preceded by a saturated solution of mercuric chloride.

The effect of this compound, as already pointed out, is to form a double chloride of silver and mercury, grey at first, but which subsequently becomes converted into a pure white deposit. When in this state if

Ammonium sulphide . . .	50 cc.
Water	1 litre

is applied, a double sulphide is formed of an intense black. Dilute ammonium hydrate may also be employed, as already stated, in place of the sulphide.

As regards the treatment of an image with copper bromide, this salt may be formed by dissolving 1 gramme of copper-sulphate in 10 cc. of water and adding an equivalent of potassium bromide to it. This solution is flowed over the plate, and after a whitening action on the film and thorough washing, a 20 per cent. solution of silver nitrate is applied.

Fixing the Image.

As regards fixing the image, nothing need be said excepting that the solvent used must be incapable of readily attacking the metallic image, and such are the solutions of sodium hyposulphite and potassium cyanide. It will be useful here to point out the mode by which this solution is effected. Supposing, for instance, the image be developed on the iodide of silver; we have on addition of sodium hyposulphite either

Silver iodide.	+	Sodium hyposulphite	=	Double hyposulphite of silver and sodium	+	Sodium iodide.
AgI	+	$Na_2S_2O_3$	=	$AgNaS_2O_3$	+	NaI

or,

$$AgI + 3\,Na_2S_2O_3 - Ag_2Na_4\,3(S_2O_3) + 2\,NaI$$

The first silver hyposulphite is very soluble in water whilst the last is very insoluble; we have, therefore, in using sodium hyposulphite, a danger of the formation of the insoluble compound—a danger not to be under-estimated in the matter of silver prints, when the elimination of the less soluble compound is a matter of great difficulty.

With potassium cyanide the danger does not exist, for though silver cyanide is formed, yet it is readily soluble in a small excess of the potassium compound.

Silver iodide.		Potassium cyanide.		Double cyanide of silver and potassium		Potassium iodide.
AgI	+	$2\,KCN$	=	$AgCN{\cdot}KCN$	+	KI

Instead of AgI in the above equations, we may substitute nearly every silver compound—thus $AgNo_3$, $AgCl$, $AgBr$, $AgOSiO_2$. Potassium cyanide, however, has the drawback that it is excessively poisonous, and that the presence of acid causes it to evolve hydrocyanic acid, a gas the deadly effects of which it is unnecessary to comment on. Another drawback to its use is the danger that exists of its dissolving up the finely deposited metallic silver, of which the half-tones of the image is composed. If used

in a sufficiently weak solution, however, the solvent action need not be feared. All traces of the hyposulphite and cyanides should be removed by thorough washing, otherwise the transparent parts of the image might discolour, or a disintegration of the film might take place through crystallisation.

The following solutions are those generally employed:—

Sodium hyposulphite . . .	100 grammes
Water	500 cc.

And,

Potassium cyanide	30 grammes
Water	500 cc.

Varnishing the Film.

The collodion film being excessively delicate and easily torn or scratched, photographers have adopted the plan of covering it with a transparent film of hard resin. This is effected by dissolving the resin in spirits, such as alcohol, and flowing it over the surface. In practice it will be found that, in order with safety to cover the film without dissolving or disintegrating it, the specific gravity of the methylated alcohol, with which for economy it is made, should be greater than that employed in the manufacture of the collodion. It may at first sight seem strange that alcohol should be capable of attacking the pyroxyline, but it must be remembered that undiluted methyl compounds are solvents of it, and, unless sufficient water be present in the varnish to check the tendency, a disintegration at least will take place. It must also be remembered that the rate at which the solvent evaporates will cause a difference in the transparency of the coating. If it be allowed to evaporate spontaneously, the alcohol evaporates first, and leaves the water behind, and, as anyone will find if he drop a little varnish into water, the resin at once separates in minute particles, which, when so united together, give a translucent deposit, caused by the reflections of the various surfaces. On the other hand, if heat

be applied, and the water be caused to disappear as rapidly or nearly as rapidly as the alcohol, the resin will dry transparent, the heat being sufficient to cause the particles to be bound one to another, thus eliminating all chance of particular reflection.

The resin should be as colourless as possible, as even the thin coating given to a negative picture is often sufficient to cut off much of the actinic light if it be of a red or yellow tint. As an experiment, it is only necessary to dissolve red Australian gum in spirit or water, and apply it to a portion of a glass plate, when it will be found that sensitive chloride paper darkens much less rapidly where covered with it than where it is bare.

The constituents of most varnishes usually comprise amongst them lac and sandarac, but it is a matter of the greatest nicety to proportion them in such a manner that the film shall not split after exposure to any great variation in temperature. The cause of the contraction that takes place is not accounted for; it seems that some resins have a property of attracting moisture, and almost becoming hydrates. This might cause an expansion of the film, whilst a rise of temperature might cause contraction. The whole blame, however, must not be laid upon the varnish, as the collodion film, when not free to expand and contract as it likes, may often produce the same effect. The following varnishes have been found satisfactory:—

Unbleached lac	65 grammes
Sandarac	65 grammes
Canada balsam	4 grammes
Oil of thyme or lac acetic	32 cc.
Alcohol, ·830	500 cc.

Or,

Seed lac	120 grammes
Methylated spirit	1 litre

The lac is allowed to remain in contact with the solution for two or three days, with occasional shaking; after which the supernatant liquid is decanted off, and thinned down to proper fluidity.

CHAPTER XI.

MANIPULATIONS IN WET-PLATE PHOTOGRAPHY.

Cleaning the Plate.

THE glass plate must first be cleaned with one of the detergents indicated in the last chapter. If the tripoli powder cream be employed, it should be applied with a small pledget of cotton wool or soft rag, taking care that both sides of the plate are covered with it. It may either be allowed to dry on the plate, or, whilst still wet with the alcohol, may be wiped off with a soft diaper duster. In the latter case a little practice is required to prevent markings on the plate as shown by breathing on it. When the tripoli powder is all rubbed off, a final polish should be given to both surfaces with a chamois leather or old silk handkerchief.[1] The polishing should be such as is used in french-polishing a table; not too heavy a pressure should be exercised, and there should be a continuous circular motion. It should be remembered that the effect of rubbing silk on glass is to generate electricity, which is sometimes a cause of non-adherence of the collodion to plates. The electricity in the glass should be allowed, or caused, to be dissipated before collodion is applied. There are various appliances for holding plates during cleaning, some of which are excellent in their way, whilst others are toys made on principles unmechanical. They are not necessary for the size of plate with which an amateur is likely to work.

If a plate be clean the moisture from the breath will leave it evenly. It must be freed from dust before collodionising, by passing a badger-hair brush over its surface.

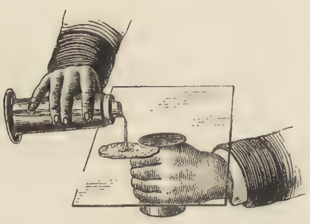
[1] Before taking these into use, they should be thoroughly cleaned from all greasy matter by washing with soda.

Coating the Plate with Collodion.

The plate may be held in its centre by a pneumatic holder, such as that in figure 11, or at the corner by the fingers, if care be taken that no portion except the edges are touched. From a half-filled 6-ounce bottle, or from what is known as a collodion pourer (fig. 11), the collodion should be carefully poured upon the plate, so as to form a circular pool at the end farthest away from the manipulator, and gradually be allowed to cover the entire surface, the wave flowing from the right-hand to the left-hand top corner, from thence to the left-hand and right-hand bottom corners, and finally into a stock bottle, whence, after decantation, and (if necessary) dilution with 2 parts ether to 1 of alcohol, it can be again employed. When the collodion is thus poured off, the plate will be in nearly a vertical position, and a gentle rocking motion should be given to it to prevent the collodion setting in ridges; but the precaution should be taken not to grind the edges against the bottle, otherwise particles of glass may appear on subsequent plates. In hot weather the collodion does not take so long to set as in cold. The state of the film can be always ascertained by cautiously touching the left-hand bottom corner with the finger. When no longer tacky, the plate is ready for immersion in the bath. The collodion should be filtered if necessary, or it may be decanted from a stock bottle by one of the ordinary syphon arrangements.

Fig. 11.

Fig. 12.



Sensitising the Plates.

The film of collodion having set, the plate is immersed in the sensitising solution contained in a vertical or horizontal bath, the former being recommended for small plates, though the latter is essential for large sizes. A 'travelling bath' is perhaps the best form of bath holder, as it is useful for indoor and also for outdoor work. It is of the form given in the figure. The top of the glass solution-holder B, which is held in a case A, is closed by a water-tight india-rubber top D, screwed down by the screws C as shown. The 'dipper' employed for carrying the plate into the solution during

Fig. 13.

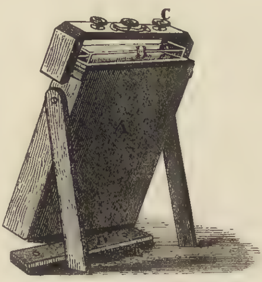


Fig. 14.

Fig. 15.

the operation of sensitising may be conveniently made of PURE silver wire, of the accompanying shape. It is usually, however, made of ebonite or glass. When the plate is covered with the solution by a steady downward motion of the dipper into the bath, it is moved slightly up and down

in the fluid to wash off the ether from the surface of the film, and, when all greasy appearance has vanished, it may be left quietly at rest for from one to five or six minutes, according to the temperature and amount of bromide[1] present. The motion of the plate in the bath at first is important; as, if neglected, streaky negatives are apt to result, especially in summer weather.

It need scarcely be said that the silver nitrate solution should be free from all sediment before a plate is immersed in it, and it should be kept in order as shown at p. 62. After being *very slowly* withdrawn from the bath, capillary attraction will be exercised by the solution in the bath on that left on the film, and there will be but a slight quantity left on the plate, quite insufficient to cause the necessity of long draining. On the other hand quick withdrawal necessitates long draining on a pad of blotting-paper; the edge that occupied the lowest position in the dark slide should be pressed against it. When the surface appears free from excess of moisture, the plate is placed in the dark slide, taking care that the edge that is to occupy the top place in the camera is kept in the same relative position. The slide is closed after the back of the plate has been dried with a piece of rag or blotting-paper. It is here presumed that the camera is in position, and that the view has been focussed, following out the rules given in Chap. XXXII., p. 242, and that the exposure is given also in accordance with the remarks to be found on p. 246.

Development.

Having decided which developer is to be employed, making the decision after a careful study of the picture, and noting its peculiarities, the plate is removed from the dark slide, the same precaution of keeping uppermost the edge which

[1] The greater the amount of soluble bromide in the collodion the longer it takes to sensitise fully.

occupied the top in the camera being taken as before. If this were neglected the bath solution which might have accumulated at the bottom edge might flow back over the surface, and thus inevitably cause irregular development if nothing worse. The developing solution having been placed in a clean cup, it is swept with an even motion, without being allowed to stop, over the plate, which is held by a pneumatic holder, or by the fingers, as in coating it with collodion. Little or none of the solution should be allowed to leave the film, unless it be feared that too much density will be given to the resulting image, in which case it is an advantage to let it wash off a portion of silver nitrate. As the picture appears, the developer is caused to work round to every corner in succession, thus securing an evenness which would otherwise be wanting. An over-exposed picture will flash out at once, and, unless the plate be immediately washed, a veil or fog will inevitably be deposited on the surface, caused by the too rapid reduction of the first particles of silver, and the consequently rapid reduction of the remainder. An under-exposed picture will develop very slowly, and will always be wanting in detail by transmitted light, though it may appear fully out when looked at by reflected light, if held over a black background such as the coat-sleeve.

A properly exposed picture should develop gradually and evenly, and should take at least half a minute in warm weather to come fully out in every part. When no further action is manifest, the developing solution should be thoroughly washed away, and the next operation should be proceeded with.

Intensifying the Negative.

This operation is one in which great judgment is required by the manipulator. Too great an opacity will spoil the negative, giving a black and white picture when printed ;

whilst, on the other hand, one not sufficiently opaque will yield a grey print, which is unsatisfactory. The opacity must be judged of by the *colour* of the deposit as well as by the *density*, though the former need not be taken into account when the iron developer has been used, as the silver deposit caused by it is of a blackish grey. If a pyrogallic acid developer be employed the colour is of a decidedly reddish tint, and proportionally non-actinic, hence great judgment is necessary to ensure a really good result. When intensity is procured by using the pyrogallic solution the same remarks hold good, though the colour is never so marked as when arising from development. Whatever course be decided upon, it should be borne in mind that the general character of the finished negative will always bear an exact relation to that given by the primary development. Thus a flat-looking developed image will yield a flat-looking picture, whilst one full of gradation will yield one similarly graduated.

Should intensification be necessary, the operator must determine whether it would be more advantageous to conduct it before fixing the image, or afterwards. Should over-exposure have been given the latter will be advisable, whilst, if undue exposure, it should certainly take place before fixing. The intensifier should be poured over the plate, and, whilst so remaining, a few drops of the silver nitrate solution (p. 71) should be dropped into the cup, and then the intensifier poured back. The solution is again swept over the plate, and the required density is obtained by removal of the silver.

It has been a point causing some discussion as to whether a developed picture may see light before being intensified. The answer to this seems simple. With an iodised film, which has been well washed after development, it may be exposed to tolerably bright light without any danger of producing a veil by the action of the intensifier, since silver iodide is almost insensitive to light, except in the presence of an iodine absorbent. With a

bromo-iodised film more caution is required, though the writer has never found that a short exposure in a moderately strong light is hurtful. With a bromised film the less exposure given between the two operations the better.

When intensifying after fixing, it is customary to flow a little iodine (see p. 72) over the film, then to expose it to light, and afterwards to use the pyrogallic solution. This is nearly useless unless a little free silver nitrate be present, or all excess of iodine be washed out, any trace of which would render the exposure inoperative. The writer recommends a little bromine water instead of the iodine, for reasons which will be apparent on reading the chapter on emulsions.

In intensifying after fixing, there is a danger of staining the shadows with a reddish stain. This seems to be more due to a pyrogallic stain than to deposited silver, and can usually be got rid of by a little acetic acid diluted with an equal bulk of water.

For landscape or portrait negatives it is seldom wise to resort to any method of intensification, except that with silver, as there is great risk of making the half-tones too opaque. The iodide of mercury formula (p. 72) is perhaps the best, if anything more be necessary.

Fixing the Negative.

This operation calls for little remark. The plate may be immersed in a vertical or horizontal bath if the sodium hyposulphite solution be employed, or it may be applied by flowing it over the plate : this should always be done with the cyanide solution. Attention should be paid to see that all the iodide, bromide, or both be dissolved away. This can be ascertained by reversing the plate and noting if the yellowish-green colour due to them be absent. Finally the plates should be well washed and drained. A neat contrivance for holding the plates when drained is shown in fig. 16. As it folds up it is suitable for field work, though a draining

box is usually carried, made as in the accompanying sketch, fig. 17.

FIG. 16.

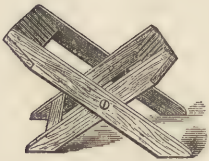
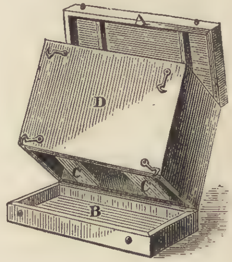


FIG. 17.



Varnishing the Negative.

The plate may be allowed to dry spontaneously or by the aid of heat; the latter method gives a slightly denser image, and therefore a negative should never be heated when parts of it are dried by ordinary evaporation. Before applying the varnish the plate must be warmed (see p. 75), to cause the varnish to flow, and also to prevent it drying matt. The varnish is applied like collodion, the same procedure being followed exactly. When all that will has run back into the bottle, any excess that may have collected at the corner end may be removed by pressing the glass on a pad of blotting-paper. The plate must again be warmed.

The sources of heat are various. In India, or in other hot climates it will be found that exposure to the sun's rays imparts sufficient warmth to the glass. In temperate climates the neatest way of attaining the proper temperature is by placing the plate in a hot-air bath, as used in chemical operations (see fig. 26); failing which, a clear fire, a Bunsen rose burner, or a paraffin lamp may be brought into requisition. A naked spirit-lamp is dangerous without great care, and the solvents of the varnish, being highly inflammable, readily catch fire from any naked flame.

CHAPTER XII.

DEFECTS IN NEGATIVES.

A MERE mention of some of the defects that are to be met with in negatives will suggest a cure, whilst for others, which are a little recondite, explanations will be offered and remedies suggested.

'Fog' on a negative may be due to several causes:—1, it may be due to a dirty plate; 2, to over-exposure; 3, to an alkaline bath solution; 4, to want of acid in the developer; 5, to improper exposure to actinic light, either in the camera or dark room; 6, to vapour in the developing room or tent. A minute examination of the condition of the negative and the state of the dark room or tent, will generally show the cause of the defect, which has only to be known to be rectified.

A weak image may be due—1, to an unsuitable collodion, a weak sensitising bath; 2, a bath charged with organic matter; 3, bad lighting of the subject due to dull weather or a yellow light; or, 4, an over-strong developer.

Pin-holes in the negative may be caused by—1, dust on the plate; 2, the bath being over or under iodised.

Black specks on the picture are usually due to—1, dust in the camera; 2, slide; 3, dark room; or, 4, dust in the collodion.

Comet-like spots are almost always due to undissolved particles of pyroxyline in the collodion.

Transparent spots, as distinguished from pin-holes, are usually due to dust in the collodion.

A scum on the film is usually found when a plate has been kept for a long period out of the bath, or when a too strong development has been used. A plate which is to be

kept for a long time before development should be sensitised (or finally dipped) in a weak bath, and only immersed in it sufficiently long to cause all repulsion between the surface of the plate and the solution to be overcome. A collodion containing a larger than usual proportion of bromide is also recommended to secure freedom from stains.

The usual explanations given as to the cause of markings like watered silk, is that the collodion contains too much iodide, is too alcoholic, or that the pyroxylin is too strong. The remedies have already been indicated. Black stains at the corners of the plate are often caused by the bath solution flowing back over the sensitised surface, after having been in contact with the wood of the dark slide.

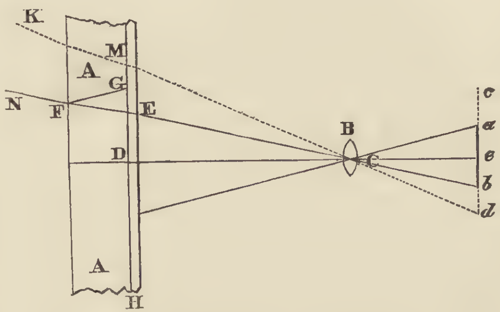
Transparent markings are much more common in cold than in hot weather. They generally arise from unequal sensitising of the film in the bath, and from the developer refusing to flow.

A want of sharpness in a picture may be due to inaccurate focussing, to a want of achromatism in the lens, or to the camera being shaken accidentally by the wind, or by the sinking of the camera legs during the exposure. If the lens be in fault there is no help for it but by ascertaining how much further backwards or forwards the ground glass of the camera ought to be shifted in order to get the sharpest result possible. This can easily be found by actual trial, and when noted the ground glass may be permanently placed in such a position relatively to the glass plate in the dark slide, that when the picture is visually in focus the position of the sensitive plate shall be chemically in focus.

A blurring of the image can easily be accounted for; though, perhaps, there has been more controversy on the subject than on any other photographic phenomenon. It is usually ascribed to geometrical reflections of the incident rays coming through the lens from the back surface of the glass, and no doubt, in some cases, this is absolutely true, though in others it requires a more complete explanation.

It must be borne in mind that the rays of light do not strike the surface of the plate perpendicularly except at its centre. The accompanying diagram shows a glass plate, A A, of exaggerated section, with rays of light passing through the optical centre, C, of the lens, B, coming from a bright line, *a b*. The ray *e* C D is perpendicular, and the ray *b* C E makes an angle with the perpendicular. This last ray, after passing through the collodion film (which for the time we may consider transparent) would be bent inwards to F, and a

FIG. 18.



portion would be reflected from the back surface of the plate, and strike the thin collodion film again at G. From G, a portion might be reflected again, and so on. Evidently, in this case, a blurring might take place, but always *outwards* from the centre of the plate. If, however, the ray of light *b* C E proceeded from the extremity, *b*, of the dotted line, *b d*, which may be supposed to represent a bright line of light, then no blurring would be apparent, as the blur from it would be covered by the image E M, of the bright line. Now in practice blurring is usually most intense when a dark object, such as a tree, is opposed to a bright object, such as the sky; in which case we may suppose *b d* to be a section of the sky, and *a b* of the tree, which we may suppose to be a dark line in section. Here the blurring is evidently

not due to reflections of the incident rays from the glass. To account for it, we must look to another feature of the sensitive surface. If a sensitised film be examined under the microscope it will be found to consist of minute grains of silver bromide, iodide, or bromo-iodide, and each of these grains individually must reflect more or less light from its surface. A beam of light, therefore, must be dispersed in every direction, and, as has been shown,[1] the light striking at any point of the film is scattered and reaches the back surface of the plate as a disc, with intensity gradually diminishing from the centre. The reflection from that surface becomes most noticeable when the critical angle of the glass is reached. The direction that the rays take in striking the particles is not of any great moment, as the difference in intensity of the reflections in any one direction is very slight when the angle does not differ very largely from a right angle. Hence it is seen that blurring really takes place from this cause in all parts of a picture taken on a glass plate, but that it is naturally most apparent when a bright light is opposed to a deep shade. There is still another point in this particular scattering of the rays to take into account, and that is, the lateral scattering. Supposing the intensity of the light in the lateral direction to be only $\frac{1}{100}$ of that in the perpendicular, the penetration into the film would still be considerable, and a blurring would result on this account. In photographing fine lines close together this kind of blurring is often most apparent, a black line being often filled up, or rendered too fine. It has been argued that blurring is also due to the lens, but a serious consideration of the matter will show that such an effect is hardly possible if it be tolerably achromatic.

The blurring caused by the reflection of the scattered rays from the plate can be destroyed by using an opaque body, on which the collodion shall rest, or it can be partially eliminated by placing a backing of some black or non-

[1] See *London, Edinburgh, and Dublin Phil. Mag.* January 1875.

actinic colour in optical contact with the back surface. The lateral blurring is a more difficult enemy to face. It can be avoided by dyeing the film with a scarlet or yellow dye ; but this is at the expense of sensitiveness. It may be eliminated also by making the film as transparent as possible (that is, by reducing the particular reflection). This is only feasible in dry-plate processes, and then is only occasionally successful. A daguerreotype plate should be free from all blurring, except the very minute amount which may be due to the last-named cause.

CHAPTER XIII.

POSITIVE PICTURES BY THE WET PROCESS.

THERE is no very distinctive difference between the manipulations or the theory of the negative and positive processes. Any distinction between the two may be summed up in this : the metallic image must be of as white a nature as possible, whilst the background must be as dark as possible. The image should also be as transparent as circumstances will allow, for it must be remembered that all half-tone is dependent on this quality, and that in the half-tone consists the value of the picture. After a microscopic examination of a film it will be manifest that the coarser the grain, the more colour should be capable of being seen through the image ; hence it is not amiss to have the developer of such a nature as will produce this effect, and also to cause the silver deposit to assume as white a character as possible.

The bath is usually made as follows :—

Silver nitrate	65 grammes
Water	1 litre

The silver iodide is added, as for the negative bath (p. 61). It should be slightly acidified with nitric acid.

If a pyrogallic acid developer be employed, that given at p. 71 is perhaps as good as any. An iron developer may be advantageously made with a large proportion of ferrous nitrate, in order to secure the white deposit. The following is a formula usually adopted.

Ferrous nitrate	7 grammes
Ferrous sulphate	3 grammes
Nitric acid, 1·45	1·25 cc.
Alcohol	Quant. suf.
Water	1 litre.

Should the deposit formed by this developer be too granular, a little more ferrous sulphate must be added. The pyroxyline for the collodion should be prepared with weak acids, about equal parts of the sulphuric and nitric acids being employed, with as much water as they will bear without dissolving the cotton wool when the temperature is lowered 5° below that given for preparing negative pyroxyline.

The collodion should contain more ether than alcohol when such pyroxyline is employed. The writer has found that the following gives satisfactory results :—

Ether, ·725	400 cc.
Alcohol, ·812	300 cc.
Pyroxyline	10 grammes.

The following may be added to this quantity of plain collodion—

Ammonium iodide	7 grammes
Cadmium bromide	1·5 grammes.

As in iodising negative collodion, it may be found advisable to omit 150 cc. of alcohol from the collodion and to dissolve the iodide and bromide in it, and subsequently to make the addition when the collodion is required for use. A little tincture of iodine, enough to give a sherry colour to the collodion, is usually necessary to secure sufficiently

dense pictures. The development should not be carried to such an extent as in the negative process. A picture on a glass support, when viewed by transmitted light, should, in fact, look under-exposed. If the support for the collodion be a ferrotype plate, the image may be developed very readily so as to give the best effect, or the black background can be used to assist the judgment. It need scarcely be said that when glass is employed the back of the plate should have black velvet or black varnish in contact with it. Bates's black varnish is recommended for backing the plate. The fixing solution is the cyanide solution, given at p. 75.

CHAPTER XIV.

DRY-PLATE PROCESSES WITH THE BATH.

It is not proposed to enter into details of many dry-plate processes, as they can be ascertained by the consultation of various manuals. At the same time it is thought advisable to enter more fully than usual into the theory of the subject. The course usually adopted for these processes is as follows :—

The plate is coated with a preliminary substratum of gelatine, albumen, or india-rubber, or else is given an edging with one of them. The collodion is then applied, and sensitising takes place in the usual manner. The silver nitrate solution is next thoroughly washed off in distilled or rain water, and what is known as a preservative is flowed over the surface of the plate. The preservative may be partially washed off, or it may be allowed to dry on it in undiminished strength. The plate is now in a state ready for exposure.

The preliminary coating or edging of albumen is given to the plate in order to secure the adhesion of the collodion film. It is found in practice, if this be omitted, that the

film, on being wetted, becomes non-adherent, and floats off. The substratum, as it is technically called, must always be of such a nature as not to injure the bath solution, and, to guard against all risk, it is advisable that every portion of it should be covered with collodion. The following are formulæ for it :—

Albumen	1 part
Water	50 to 100 parts
Ammoninm hydrate—Sufficient to give it a smell of ammonia.	

Or

Sheet gelatine	3 grammes
Ammonium hydrate . . .	15 cc.
Water	1500 cc.

The gelatine should be soaked in half the quantity of water, and the remainder added boiling. When cool, the ammonium hydrate should be dropped into the fluid. This solution will not keep, hence it is advisable to make it up only just when wanted.

When it is required to cover the entire plate with either of these substrata, it is usual to wet the plate with distilled water, and flow it over, and drain. It frequently occurs, however, that this method produces markings on the negative. A simpler and more effective plan is to cover the end of a glass plate (the breadth of the plate to be covered) with a piece of fine flannel or swan's-down calico, to moisten it with the fluid, and then to squeeze out all excess. This brush, known as Blanchard's brush, is drawn down the plate with an even stroke ; it gives the very finest coating possible. A washed and unpolished plate seems to take more kindly to the colloid body than if the cleaning be finished off with the silk hand kerchief or chamois leather.

In lieu of either of the above solutions the following may be flowed over the plate like collodion, and be allowed to dry spontaneously :—

India-rubber	1 gramme
Benzine	500 cc.

The collodion should be of such a character as to give great density to the developed image. It should also give a porous film, for it must be remembered that when the pyroxyline parts with its water of hydration it becomes extremely impermeable to all solutions; so much so that a horny collodion will often refuse to develop. It has been the practice with many practical photographers to keep the iodised collodion till it is thoroughly aged, and has a ruby tint from the elimination of iodine from the iodides of the alkalis, and the consequent combination between the alkali and the pyroxyline. This effect is precisely similar to that obtained by a modification of the ratio of the acids to the water in the manufacture of the pyroxyline. Collodion may also be rendered porous by adding water to a portion of it to such a degree that it gives a reticulated film, and by then adding the remainder unwatered. A slight opalescence of the film is not objectionable, and it may even dry almost matt, so long as the necessary disintegration of the pyroxylin is secured, since it is found that varnishing takes away the dead appearance to a great degree.

The sensitising bath should be such as to give a good dense film after the plate has been immersed some time. The solution employed for the wet negative process is of proper strength, unless the collodion be highly bromised, in which case the amount of the silver nitrate may be increased to half as much again, or even to twice the quantity.

After sensitising, it is usual to wash the plates to such an extent as to free them from all silver nitrate solution. The first washings are usually made in distilled or filtered water. Rain water is often recommended, but the operator should beware of it, unless it be very clean and at least be twice filtered. Perhaps more bad dry plates are produced by the use of impure washing water than by anything else. When the delicacy of the effect that is produced by the ethereal waves of light on the pure products is taken into consideration, it will be apparent that every extraneous force which

will overthrow the equilibrium of the particles should be avoided. Thus we might expect that hydrogen sulphide might cause that overthrow, and it inevitably produces fog. A moderate proportion of iron in the water would also produce like results. When the first excess of the silver solution is washed away the danger of the use of impure water diminishes rapidly, and almost any *ordinarily* pure water may be brought into requisition, but in any case a final rinse of distilled water is to be strongly recommended. Care should be taken that the surface of the plate after withdrawal from the bath is covered by the water without stoppage. The first washings may be well performed in a dish, and an even covering of the surface can be attained after a few attempts. Washing in distilled water should continue till all repellent action due to the alcohol and ether contained in the bath solution disappears.

Applying the Preservative.

The preservative is usually applied by floating it on the surface of the film for about a minute. Care should be taken that its strength is not diminished by too much water being left on the plate. In some cases it may be applied by immersing the plate in a flat dish or dipping bath containing it. There are some objections to this mode of application however.

It will be convenient here to discuss the ends to be obtained by the use of a preservative. 1. It must be an iodine or bromine absorbent, for without this quality the film manifestly might be insensitive. 2. It must be capable of filling up the minute pores of the collodion, so that on re-wetting after drying it may give access to the developing solution. 3. It must act as a protective varnish against the atmospheric influences. Regarding the first point there is not much difficulty, as nearly every organic animal or vegetable compound is capable of combining with iodine.

Under the head of absorbents we may rank tannin, pyrogallol, gallic acid, gums, gelatine, albumen, caffeine, theine, and other like bodies. The second requirement may be met by the employment of some of the above, or by the addition to them of sugar in various forms. The last requirement is more difficult to meet, and is very often neglected, as it entails that the body should not be hygroscopic. The drawback to any processes, for instance, in which the preservatives contain gum arabic, is that moisture is attracted, and the sensitiveness of various parts of the plate is affected. No better varnish is known than albumen, though this has its disadvantages as regards rapidity, unless the greater proportion of it be removed previous to dessication, or unless it itself becomes a vehicle for holding the sensitive salts, as in the collodio-albumen process. In the writer's opinion an unexceptionable preservative has yet to be found. It appears dubious whether it will not become advantageous to dispense with it altogether, when the balance between the pyroxyline and sensitive salts is properly adjusted, as in the case of emulsion plates. It must then be borne in mind that the word 'preservative' is only employed for want of a better.

Drying the Plate.

Ordinarily speaking the film is allowed to dry spontaneously, for which purpose a cupboard or box should be fitted up in the manner described in the various hand-books. Another plan that may be adopted by the student, if the plate be not too large, is the use of the hot-air bath, employed in chemical laboratories. The author has found that up to $8\frac{1}{2} \times 6\frac{1}{2}$ inches this method is useful. It is found convenient to allow the doors to be left open till the surface moisture has disappeared, after which they may be closed and the plates be allowed to dry at the higher temperature. Half a dozen plates may be dried by this means in half an hour.

Development.

It is usual to apply a narrow edging of india-rubber solution round the plate by means of a piece of stick, or by a piece of blotting-paper held in the fingers and run round. A prettier piece of apparatus which is sometimes employed to give the edging is the following :—A camel's-hair brush, B, is held in position by a couple of wire loops, C C, inserted in a stick, A, and so arranged that the brush may be lowered into the solution without wetting A. The bottom edge of the stick is brought against the edge of the plate, so that the brush rests on the film, and having drawn round the plate, a neat edging is given. The strength of the india-rubber solution may be five times that given on p. 92. There are two methods of developing dry plates. The general principle of one is the same as that given for the wet process, though modifications must necessarily arise from the absence of silver nitrate solution on the film. The other is totally different, and may be employed when the sensitive film contains even the smallest proportion of silver bromide, being dependent on the fact that certain re-agents have the power of reducing silver sub-bromide and bromide silver to the metallic state. It is generally admitted that iodide is unsuitable for this method of development, though it is known that it may be made amenable to it. The re-agents employed are invariably those compounds which have a strong affinity for oxygen. We have seen that amongst these is pyrogallic acid, and it can also be shown by direct experiment that it also has a strong affinity for bromine when a body is present which will easily part with it. Gallic acid and other derivatives possess similar properties, which in all cases are powerfully increased by the addition to them of an alkali.

FIG. 19.

The following experiments should be made by the student

that he may become acquainted with all the phenomena connected with this class of development.

1. Precipitate pure bromide of silver, say 4 grammes, and wash thoroughly; then place it at the bottom of a test tube, and cover it with a solution of pyrogallic acid (about ·3 gramme to the 100 cc.), to within a short distance of the top. Having drawn out from $\frac{1}{2}$ inch tubing a fine funnel, let him place the end drawn out just above the bromide, and then pour into the funnel 3 or 4 drops of strong ammonia. It will be seen almost immediately that a black layer forms above the bromide, that the silver is reduced, and that the action continues for a certain time, and then stops. The blackening of the liquid will be found to be due to the alteration in the pyrogallic acid, consequent on the absorption by the alkali of the bromine abstracted from the bromide.

FIG. 20.

2. Repeat the experiment, replacing the pyrogallic acid by dilute ammonia (say, ·880 sp. gr. diluted with 10 times its bulk of water), and drop into the funnel a small quantity of strong pyrogallic solution. The phenomena presented will be slightly different. A cloud will instantly form in the ammonia, and if the surface of the bromide has been protected by a small diaphragm of paper, the whole of the solution may be poured off, and the surface of the bromide will be found almost unchanged. The difference is caused by the *solubility* of silver bromide in ammonium hydrate; and the portion held in solution is consequently more readily reduced than that remaining in the solid state.

3 and 4. Repeat these two experiments, substituting potassium hydroxide (caustic potash) for the ammonium hydrate. The phenomena presented in both cases will be identical; the silver bromide will be reduced from the solid

state. This is because *silver bromide is insoluble in the potassium compound.*

5. The next experiment should be to dissolve a small quantity of silver bromide in ammonia, and then drop into the solution a small quantity of potassium bromide solution. It will be found that a precipitate is immediately caused, which, on analysing, will be found to be silver bromide combined with ammonia.

6. Repeat the foregoing experiments with silver iodide, first with weak solutions, and then with concentrated. It will be found that the concentrated will act upon the iodide, whilst the weaker will not. The iodide not being soluble in ammonia, the phenomena described in experiment 2 will not be observable.

Reviewing these experiments, we are led to the following conclusions :—that the alkaline pyrogallates have such an affinity for the halogens that they are capable of breaking the bond existing between the silver and the bromide ; that the portion which is soluble in the alkali is most readily acted upon ; and that the addition of a soluble bromide diminishes the amount capable of being dissolved. Consequently, if a surface of silver bromide were treated with ammonium pyrogallate, we should expect that the undissolved bromide was less readily reduced than that portion which is dissolved, and that less immediate reduction would take place when a soluble bromide, such as that of potassium, were present.

In practice this is found to be true ; and there is this further peculiarity observed, that the sub-bromide is more easily reduced than the bromide. Now the invisible image is formed of this sub-bromide, and, if ammonia be the alkali employed, we have first a reduction of this sub-bromide to the metallic state ($Ag_2Br = 2\ Ag + Br$) ; a small quantity of the bromide is dissolved, and the metallic silver reduced from it is immediately precipitated on the image thus formed. Additional strength is also given to the image from the fact

that the bromide, immediately in contact with the primarily reduced silver, is more easily reduced than that not so situated. It may be that freshly reduced silver is capable of combining with the bromide, to form fresh sub-bromide ($Ag + AgBr = Ag_2Br$). At any rate, an action of somewhat this description takes place in the film. An interesting experiment is confirmatory of this. Take an ordinary dry plate, such as an albumen-beer plate, and expose it in the camera. Coat half of it with a bromide emulsion, and develop it by the alkaline method. That part coated with the bromised collodion will be found to acquire density. When dry, remove the film from off the glass plate with gelatinised paper, and also cause the adhesion of a similarly prepared gelatine paper to the surface primarily next the plate. When nearly dry, the exposed film can be split off from the bromised film; and on examination it will be found that there is an image on both films. If the sensitive salt in the collodion film exposed in the camera be iodide, an image may be developed, though it will be weak.

The fact remains then that this action takes place, even though the films be separated by a very thin layer of albumen. It will also be apparent that the image will be stronger when developed with ammonia than with potash, for with the former the silver can be deposited from the solution. The writer has been able to intensify images from alkaline or neutral solutions of sodium hyposulphite and potassium cyanide, in which have been dissolved silver chloride, by this action of pyrogallic acid. The soluble bromide seems to play a twofold part with ammonium hydrate. It renders the silver bromide less soluble, and, as is known, forms a double bromide with that of silver. With potassium hydrate its only effect is to form the double bromide; it prevents the solution of too large a quantity of the silver salt. The combination between the soluble bromide and the subbromide is perhaps less certain; a combination with a part of the latter may take place, and probably does, leaving

outside it one of the atoms of silver. The mere fact that the metallic silver is in proximity to this new molecule probably determines the reduction of the latter to the metallic state, its attraction upsetting the tottering equilibrium which exists for a moment after the developer has been applied.

It should be noted that the same treatment of the bromide is effective when gallic acid is employed instead of pyrogallic, the power of reduction of the former being smaller than that of the latter. This fact proves that with a weakly formed invisible image the latter should invariably be used.

In the silver bromide emulsion plates, for which this development is particularly adapted, it will be noticed that in order to obtain pictures which are free from veil or fog, one of three conditions is necessary—either there must be a little soluble bromide in the film, or else if there be an excess of silver nitrate there must be some free mineral acid or silver chloride formed by the decomposition of some metallic chloride present.

These conditions are apparently conducive to the formation of bright images. It will be profitable, however, to consider the probable cause of this. Bromide of silver is usually formed by the double decomposition of silver nitrate and soluble bromide, such as a proportion of potassium with that of cadmium. Cadmium and other dyad metals may form two bromides, the ordinary bromide and a sub-bromide. In ordinary circumstances the latter compound is found in very small quantities, but when it comes in contact with silver nitrate, a sub-bromide of silver, or, otherwise, bromide of silver with unattached atoms of metallic silver, is formed. When the soluble bromide is in excess, these molecules—supposing them to be half molecules of silver bromide together with the attached atoms of silver—readily attract the excess of soluble bromide; and, when these atoms of excluded silver lose their nascent power of attraction, they become incapable of causing a reduction of the neighbouring bromide when a developing solution is applied. If, however, these

sub-bromide molecules remain as such, the action of the reducing agents is to attack these first, and the reduced silver exerts its power in determining the reduction of the neighbouring molecules; in other words, causes reduction where light has not acted. When there is free nitric acid which can act on the molecules, we have another action taking place. The nitric acid is capable of reducing to the state of bromide the small number of molecules of sub-bromide which may exist, by converting the loose atoms of silver into nitrates. Thus, Ag_2Br is decomposed into $AgBr$ and $AgNO_3$; or, if the nitric acid be applied to the soluble bromide, such as Cd, before its contact with the silver nitrate, we probably have a precisely similar reaction. This explanation is founded on experiments which have lately been published.[1] The addition of certain metallic chlorides seem to produce a similar result, preventing the formation of Ag_2Br.

As touching the strengths of the solutions to be employed, 1st. The stronger the ammonia, the greater the amount of the silver bromide that is dissolved. If the amount dissolved be in excess of that necessary to supply a gradual aggregation of silver on those parts on which a deposit has already taken place, the result must be a veil on the whole surface.

2nd. The stronger the pyrogallic acid solution in the presence of sufficient alkali, the more rapid will be the reduction of the silver bromide; hence a strong solution is very likely to cause fog even if sufficient soluble bromide be present.

3rd. The stronger the soluble bromide solution, the less silver bromide is dissolved by the ammonia, but at the same time the effect produced by light is in a great measure cancelled, owing to the formation of a compound with the sub-bromide, which is as little acted upon by the developer as the bromide itself; hence we are limited as to the amount of bromide that should be supplied if we want an intense

[1] See *Journal of Photographic Society of Great Britain*, 1877.

image, and one which is easily developable. To fix, then, a developer, we should start with the maximum amount of alkaline bromide allowable in a solution, and from that build up the maximum amount of ammonia and pyrogallic acid admissible.

In comparing the two foregoing methods of development, it is necessary to consider the different circumstances in which they may be employed. The first method, it may be said, is invariably adopted with wet-plates, for everything that is conducive to success is then present. There is solution of silver nitrate on and in the film; the unbonded atom of silver in the subsalt is in a state possessing the greatest attractive activity, and development must take place shortly after exposure. If the second method were adopted, all the silver nitrate would have to be eliminated from the film by prolonged washing; in practice it is found that the resulting image is liable to be of unequal density. Again, the proportion of bromide to iodide in the collodion is small, and as the iodide is only affected by intensely strong alkaline developers, the chance of veiling the image through the reduction of the bromide unacted upon by light is increased, if sufficiently strong solutions are employed to cause the reduction of the sub-iodide.

With dry processes the advantages rest with the second method. The development takes place hours, or even months, after exposure; consequently it is quite possible that the free atom of silver in the sub-iodide or sub-bromide has partially lost its nascent energy, and that when the free silver nitrate, together with the developing solution, is applied to the surface of the film, as in the first method, the intensity of its attraction is diminished. The same amount of attractive power may be obtained by increasing the number of molecules acted upon by light; hence what in the wet process would be a sufficient exposure, in the dry may be totally inadequate. Coming to the second method, however, the result differs. Even if the silver atom of the sub-

bromide be partially saturated, the agents employed will still naturally first attack the remainder of the molecule by taking up the bromine, and liberating the other atom of silver. Now this liberation takes place in close contact with another atom, and as the attraction varies inversely as the square of the distance, a much less attractive force is necessary in order to draw the liberated atom to its partially saturated neighbour. The atom once *in situ* attracts the other depositing atoms, and an image is rapidly built up. As a matter of fact it is found that the alkaline development causes a gain of 4 or 5 times in the matter of shortening exposure, and is therefore specially applicable to all dry processes, particularly where a large quantity of bromide is dissolved in the collodion.

The following are formulæ for the different developers :—

1.	Ferrous sulphate	2 grammes
	Water	30 cc.
2.	Gelatine	4 grammes
	Glacial acetic acid	60 cc.
	Water	400 cc.

The gelatine may be dissolved in the water, and the glacial acetic acid added to it. This is quite as effective, dissolving the gelatine first in the acetic acid, and the solution is much more quickly made. Three parts, by measure, of No. 1 should be mixed with 1 part, by measure, of No. 2, and after filtering the developer is ready for use. It is better to mix them only a short time before they are required, as a slight precipitation takes place if they be kept long together. To every 4 cc. of the developer 1 drop of a 60 per cent. solution of silver nitrate should be added, and the application be immediately made to the plate.

The following is a pyrogallic acid developer, which is used in many dry-plate processes :—

I.

1.	Pyrogallic acid	10 grammes
	Alcohol	60 cc.

2.	Silver nitrate	4 grammes
	Citric acid	4 grammes
	Water	85 cc.

When required for use, 1 cc. of No. 1 is added to $\frac{1}{2}$ cc. of No. 2, and 30 cc. of water added.

Of the alkaline developers the following are those usually employed :—

II.

1.	Pyrogallic acid	1 gramme
	Water	40 cc.
2.	Ammonium hydrate, ·880	1 part
	Water	4 parts
3.	Citric acid	4 grammes
	Acetic acid (glacial)	2 cc.
	Water	30 cc.
4.	Silver nitrate	1 gramme
	Water	20 cc.

These formulæ are useful when developing certain dry plates containing colloid substances, such as albumen or gelatine. The details of the development will be given in describing the albumen-beer process.

III.

1.	Ammonium carbonate	5 grammes
	Water	30 cc.
Or		
	Ammonium hydrate, ·880	1 part
	Water	16 parts.
2.	Potassium bromide	1 gramme
	Water	35 cc.
3.	Pyrogallic acid	1 gramme
	Alcohol	5 cc.

A more recent developer, which possesses certain advantages, is as follows :—

IV.

1.	Potassium hydrate	1·5 gramme
	Water	10 cc.

2.	Potassium bromide . . .	4 grammes
	Water	100 cc.
3.	Pyrogallic acid	1 gramme
	Water	30 cc.

Nos. III. and IV. are known as the strong alkaline developers. (For details as to their employment, see p. 118.) They are employed with a bromised film produced in the bath, or by the method of emulsion as will be described.

When solutions to give increased density of deposit are necessary, that given at p. 71 may be adopted without modification. Intensity may also be given to the image by adopting the method given at page 73.

Though many recommend the attainment of sufficient density by the application of the alkaline developer, and indeed recommend plates, because such opacity can be gained in that manner, yet it is believed that silver deposited by the usual intensifying process will give a greater delicacy of half-tone. Perhaps the reason of this may be comprehended if an experiment be tried on a thin bromide emulsion plate. Let it be properly exposed, and developed solely with the alkaline developer. It will be found that the thickness of the film is not sufficient to give such a quantity of reduced silver as to render the highest lights nearly opaque, and if the alkaline development be continued, the lower lights will have only sufficient opacity when they are of the same depth as the former. With another similarly prepared and exposed plate, let a defined image be brought out by the alkaline method, and then intensified by the ordinary process. It will be found that the image is perfect in gradation, the highest and lowest lights being rendered in as good a scale of opacity as can be obtained (see Actinometry).

The ordinary solutions, as given at p. 75, are to be used for fixing, a preference being given to hyposulphite, if the plate be subjected (subsequent to its application) to a thorough washing.

CHAPTER XV.

GUM-GALLIC PROCESS.

Of dry-plate processes, only two will be described in detail; descriptions of others can be found in various practical works on the subject. The first that will be described is the gum-gallic process, as introduced by Mr. R. Manners Gordon. His directions are given, and if carefully attended to will give negatives of unequalled harmony.

To any ordinary collodion, 2 per cent. of cadmium bromide is added. The plate having been given a substratum, as shown at p. 92, is coated with this collodion and immersed in the sensitising bath, and allowed to remain in it from 7 to 10 minutes, according to the temperature. This length of contact with the solution is sufficient to allow most of the bromide to be converted into the silver compound. The washing should be of a thorough nature; the longer the plates have to be kept, the longer it should be continued. The preservative made as under is next applied, by floating it over the surface of the plate.

1.	Gum arabic	7 grammes
	Sugar candy	1·75 grammes
	Water	120 cc.
2.	Gallic acid	1 gramme
	Water	40 cc.

These two solutions are mixed in the above proportions.

No. 1 is best prepared by the aid of the heat of a water-bath. The following arrangement will be found useful in its preparation as well as in numerous other cases:—

C is a water-bath two-thirds filled with water; on the top are rings of varying diameter, fitting into one another, in one of which the flask A, containing the gum-water and sugar-candy, is placed. A small funnel (B) is dropped into the neck of the flask, in the conical part of which a portion of the steam condenses and runs back into the flask. This

prevents too great a diminution of the liquid whilst the gum is in the act of dissolving.

FIG. 21.

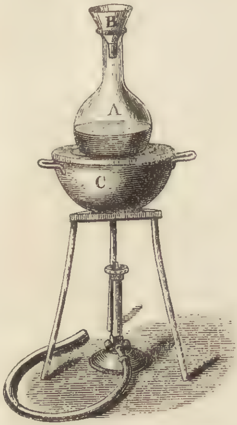
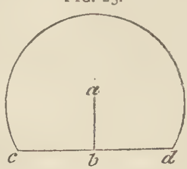


FIG. 22.

The mixed solutions should be filtered, but in this operation great difficulty is often found. The most ready method of effecting it is by the aid of a Bunsen water-pump; by an aspirator of the usual form; or by an exhausting syringe. The arrangement adopted will be seen from the accompanying sketch. The pump, or other exhausting apparatus, &c., is attached to india-rubber tubing. It is preferable to filter the solution whilst warm; when cold the pores of the filter-paper are rapidly filled up, and the solution refuses to pass. It may be necessary to fix into the funnel a platinum foil cone, made by cutting a piece of platinum foil in a circle, and cutting off a sector, as indicated in the annexed figure. In any case the filter-paper should be thin, and free from iron.[1]

FIG. 23.



[1] This may be detected by moistening it with hydrochloric acid, and letting fall on it a drop of potassium ferro-cyanide.

The preservative solution is floated over the plate, and, after remaining on about a minute, is allowed to dry. If the surface appear dull, it should be dried by artificial heat previous to exposure in the camera.

The exposure varies according to the different modes of development. If the gelatino-iron developer, given at p. 103, be employed, it should be *at least* 4 times that given to a wet plate, and if required to be kept for a long time before being developed, 20 times is not too much. On the other hand, if the strong alkaline developer, as given on p. 104, be employed, the exposure may be reduced by three-fourths, that is to say, that a plate developed soon after exposure is as rapid as a wet plate, whilst if an interval elapse of six months or so before development, then 5 times the exposure necessary for a wet plate should be given.

In order to develop the image the plate should be immersed in water of not less than 16° C. If the iron developer be employed the time of immersion should be two or three minutes, whilst if it be the alkaline developer No. III., page 104, a mere moistening is sufficient. The method to be adopted with the former is that already described. When the detail comes well out, the intensification of the image is given by the ordinary pyrogallic acid solution (p. 71). These plates are excellent when employed in a fairly dry climate, but they are disappointing when much atmospheric moisture is present; the gum softens and absorbs water, giving rise to spotty pictures. This seems to be due to a fungoid growth upon the gum, and there is no apparent remedy for it.

The negatives taken by the gum-gallic process, under favourable circumstances, are everything that can be wished for, being delicate, full of detail, having the well-known bloom, and being fairly sensitive even with the iron developer. In the hands of Manners Gordon it has proved the most trustworthy of any bath dry-plate process (except one) with which that eminent photographer has worked.

ALBUMEN BEER PROCESS.

This process has been fully described in another work by the writer,[1] and is given as therein described. It was introduced by him for solar photography, and was employed by the English Transit of Venus expedition. It is, however, equally adapted for landscape work, and is very certain in its results. The collodion employed can be that described at p. 53, though for more rapid work the following is better:—

Alcohol, ·825	450 to 350 cc.
Ether	350 to 450 cc.
Pyroxyline	14 grammes
Ammonium iodide	3·5 grammes
Cadmium bromide	9·0 grammes.

The relative proportions of ether and alcohol are adjusted according to the temperature in which the plates have to be prepared.

With the ordinary samples of collodion the usual silver nitrate bath (p. 61) can be used, but with the collodion made as above it is advisable to use a bath containing 16 per cent. of silver nitrate. In both cases rapidity is increased by the addition of 2 per cent. of uranium nitrate. It has been found advantageous to dip the plates at first in the weaker bath, allowing them to remain in it for a couple of minutes, and then to transfer them to the stronger for ten minutes more. This mode of procedure gives very sensitive and opaque films, the greater part of the actinic rays being thus utilised. The sensitiveness, however, greatly depends upon the porosity of the film, and every effort should be made to attain the maximum of this quality without injuring the texture of the film. The addition of the largest practicable amount of water to the collodion tends to give this desired porosity. After sensitising the plate is slightly washed, and the first preservative applied, which is—

[1] *Instruction in Photography.* Piper and Carter.

Albumen	100 cc.[1]
Water	100 cc.
Ammonium hydrate . . .	12 cc.

This is beaten up into froth (or is mixed by pounding it in a mortar with silica), and, when settled, the clear liquid is decanted off. The solution is mixed, immediately[2] before use, with an equal quantity of ordinary beer or stout, and floated over the plate. When bottled beer is used, it is advisable to drive off all the carbonic acid by a gentle heat. The excess is drained off, and the film thoroughly washed under the tap for a couple of minutes, and is finally rinsed with a solution of plain beer, to which 1 per cent. of pyrogallic acid has been added.

The plate is dried in the ordinary manner.

The exposure with well-prepared dense plates is often as short as that necessary for wet plates, but great latitude is admissible. With 20 times the minimum exposure necessary to secure a good negative there need be no danger of veil.

The development need not be effected for at least a month after exposure. The solutions as described in formula II., p. 104, are those employed. The following description of the development is taken from the work already referred to.

'The washing water before development should be of a temperature not less than 15° C. When the plate is washed, the following developer is employed:—To each 50 cc. of No. 1 are added 10 drops of No. 2, and after well mixing with a stirring rod the solution is floated over the plate.

'Almost immediately the image begins to appear, and after a few seconds' interval the detail can be seen by reflected

[1] Dried albumen—5 grammes to 100 cc. of water—may be substituted for the 100 cc. of albumen.

[2] This precaution is necessary, otherwise the tannin of the beer is precipitated by the albumen.

light to gradually develop. Another 7 drops of No. 2 are again added to the solution, which is once more floated over the plate. Twenty drops of No. 3 are next poured into the developing cup, and the solution from the plate poured into it. Again the plate is rinsed, this time by the acidified, pyrogallic solution, and intensification given by the use of it with a few drops of No. 4. It is not advisable to allow too much detail to come out with the alkaline solution, but to allow a portion of it to be brought out by the subsequent treatment with pyrogallic acid and silver. The alkaline developer reduces the bromide salt, and leaves the iodide to be attacked by the silver solution. It will be remarked that no restrainer such as bromide is employed; the albumen dissolved by the ammonium hydrate plays the part of a retarder, but not as a destroyer of the latent image. When the image appears sufficiently dense, it is fixed by either sodium hyposulphite or by potassium cyanide.'

There has been a good deal of dispute regarding the kind of beer to employ in the above process. Some photographers have recommended that all the chlorides of the beer should be precipitated by a preliminary dose of silver nitrate. This however, to the writer's mind, is a great mistake. The plate is at first only slightly washed, and all the chloride combines with the silver left in the film. After a subsequent washing the beer is applied again. This time the preservative is merely on the surface of the plate and not in the pores of the collodion, which have been filled up with the albumen; hence the chloride in this case cannot interfere with the sensitiveness. Any beer will answer unless it contain very uncommon adulteration. It should, however, be free from carbonic acid, as carbonate of silver is not an easy substance with which to work, tending to give markings and to cause fog on the surface of the negative.

One point in the preparation of these plates cannot be too strictly attended to, viz. to keep the fingers away from all contact with the film during preparation. A touch, however

slight, will cause a stain, and unsightly markings extending across the plate have been traced to the same cause.

CHAPTER XVI.

EMULSION PROCESSES.

We now come to a class of dry-plate processes which differ from those which have been described, inasmuch as in them the sensitive salt of silver is held in suspension in the collodion. When such an emulsified collodion is poured upon the plate, we obtain a film capable of receiving an invisible impression. The emulsion is principally formed with silver bromide, though certain other additions are sometimes necessary in order to ensure clearness in working. The silver bromide is introduced into the collodion by dissolving some soluble bromide in it, and then gradually adding an alcoholic solution of silver nitrate, the amount of which may be either in defect or excess of that necessary for the complete conversion of the whole of the soluble bromide. It is found practically that silver bromide is most sensitive when exposed in presence of an excess of silver nitrate, but most prone to give veiled images, whereas if the soluble bromide be in excess, a developable image is formed less rapidly, but greater freedom from fog is secured. Some of the probable reasons for this may be gathered from Chap. XIV. In preparing an emulsion, it is rarely possible to hit the exact proportions which shall give neither excess nor defect in one or other of the emulsion-forming constituents, and so to secure great sensitiveness with clearness; hence it is always better so to arrange the proportions that one or other shall be in known excess.

The following experiments may be made with advantage, in order to see what will be the result of having excess of the soluble bromide or of silver nitrate.

Prepare bromised collodion as given for the first process, to be described p. 115, and to 100 cc. add, in the first case, 6 grammes of silver nitrate; and to another 100 cc. the quantities given. After leaving for twenty-four hours, coat plates with these two specimens respectively, exposing before the collodion has become dried. Note their behaviour with the alkaline developer, No. III, p. 104. It will be found that with the plate in which there is excess of bromide there will be no developable image, whilst with that prepared with excess of silver nitrate there will be a fog over the image. Next take plates prepared with the same collodions and wash thoroughly under the tap. Both now will give good developable pictures, but that having an excess of bromide will require a longer exposure to give a good negative. Next, take similarly prepared plates, and, after washing, flow over them a solution of tannin, and the images will be found to be more readily developable. Again, prepare an emulsion as before, using a soluble metallic chloride instead of the hydrochloric acid, and, having divided it into two portions, add an excess and defect of silver to them respectively. Prepare plates as above, and notice the behaviour. It will be found that with the slightest excess of silver there will be inevitable fog, whilst with the defect the behaviour will be the same as that given above. Perhaps the most sensitive emulsion may be prepared by having a slight excess of silver nitrate and nitric acid, omitting the chloride altogether.

The use of silver chloride in the emulsion secures density; it does not of necessity secure freedom from fog, but, being more soluble in ammonia than the bromide, the ammonium pyrogallate readily dissolves it, and immediately precipitates it on the parts acted upon by light. It is believed that this simple explanation is capable of rendering clear the use of it, as recommended by various writers. The following rules may be laid down :—

1st. That nothing but silver bromide is necessary to give a good image, if the soluble bromide be in excess.

2nd. That if there be an excess of silver nitrate, the emulsion must be acidified with nitric or other mineral acid, or be neutralised by certain metallic chlorides, to secure freedom from fog.

With regard to the first part of this second rule, it will be remarked that the same necessity arises in the bath processes where much bromide is present in the collodion. It must also be borne in mind that if the first rule be followed, the density of the developed image will be strong; whilst if the latter (unless chloride be present), it may be weak, unless some density-giving body, such as silver nitrite, glucose, &c., be added to the emulsion, in which case good density can be obtained.

Having made an emulsion as described, it will be well to make another simple experiment. Coat a plate with it, and allow it to dry. On drying, it will be found that the soluble salts have crystallised on the surface of the plate, rendering the development of an image almost impossible. Here we have evidence that it is necessary to remove these salts. There are two ways of accomplishing this, either by washing the plate after being coated with the collodion, or by washing the whole bulk of the emulsion after allowing it to gelatinise by evaporation of the solvents. In the last method the washed emulsified collodion is dried, and the resulting pellicle is again dissolved in ether and alcohol. This process is in much favour at present; it has certain advantages about it which cannot be gainsaid; thus, the sole manipulation in getting ready a dozen dry plates is to coat them with the emulsion, and then allow them to dry. It also has drawbacks; one of the principal of which is the liability to spots on the negative, a point which is difficult to understand, since they probably will be entirely absent on plates prepared with the same emulsion unwashed. It may be said that the present state of emulsion processes is far

more satisfactory than it was a couple of years ago. Much, however, still remains to be done, in order to give them that certainty in preparation and in resulting negatives which is so characteristic of some of the bath dry-plate processes.

It is not proposed to enter into details of all the different varieties of the emulsion processes: two distinct variations will be given, one of which will be typical of an emulsion where the coated plate alone is washed, and the other of a washed emulsion. Both these will be of the simplest character, and have succeeded in the hands of the writer.

UNWASHED EMULSIONS.

Canon Beechey's Process.

The following are Canon Beechey's directions, which if followed will give tolerably certain results:—

Take Cadmium bromide (dried) . . .	90 grammes
Alcohol, ·805	1 litre,

and allow the mixture to stand, and then decant from it any quantity that may be required. To each 100 cc. of it add 1·6 cc. of strong hydrochloric acid.

Of the above solution take . .	50 cc.
Ether (·720)	110 cc.
Pyroxyline	2 to 2·5 grammes.

The pyroxyline should be that prepared at high temperature, and may contain nitro-glucose if thought advisable (see p. 48). It will be found necessary that it should stand at least a day before being used, filtering through tow only partially frees it from small particles of undissolved cotton. If much of the emulsion is likely to be required, one of the tall graduated glasses, as in the figure 24, will be found convenient, any quantity can then be syphoned or decanted off.

When the collodion is clear it is ready for sensitising:

that part which is to be emulsified should be poured into a glass beaker. For every 100 cc. of the above, take 5·6 grammes of silver nitrate and powder it carefully in an agate mortar, or by means of a glass stopper on a thick sheet of glass. Place it in a test tube, with *just* sufficient water to dissolve it, and add to it 30 cc. of alcohol, ·805. This alcoholic solution of silver nitrate should be added to the collodion (fig. 25) drop by drop, and the emulsion

FIG. 24.

FIG. 25.

should be stirred continually whilst the additions are made ; finally, the test-tube should be rinsed out with another 30 cc. of alcohol, and added to the collodion.

After the final addition the emulsion should be very smooth and rather thick, though when poured upon a strip of glass it will appear of a transparent nature. After keeping twenty-four hours, however, it will be creamy, and appear of an orange colour, when a candle flame is viewed through small layers of the liquid. This colour is indicative of a proper preparation of the emulsion, showing that the silver bromide is in a very minute state of division.

It is possible to cause an emulsion to have a decidedly bluish-green tint, in which case the particles seem to be in a different state of aggregation to that when the ruddy tinge is seen. When further improvements in the emulsion are made, it may be that this blue tint will be the mark of a more sensitive preparation. This emulsion should be used soon after the creamy state is attained, as otherwise it will again become thin, and the silver bromide will rapidly precipitate on the bottom of the bottle.

The plate having been coated with a substratum or edging (see p. 92), the collodicn is applied in exactly the same way as is the unemulsified collodion for the wet process. It is necessary that the emulsion should be rendered homogeneous, otherwise the film will appear granular. This is effected by shaking it in the bottle half an hour before it is applied to the plate. When the collodion is set, it is immersed in a dish of distilled water, or filtered rain water till all the repellent action between the solvents and the water is eliminated, and till the great excess of silver nitrate and the other soluble salts is washed out. It may then be passed through another dish of water if found necessary, and finally allowed to rest in a dish containing beer, to every litre of which 2 grammes of pyrogallic acid has been added. The best kind of beer is that known as sweet ale, the saccharine and gummy matter being more abundant in it than in that known as bitter ale. Any trace of silver which may remain in the film combines with the organic matter, and the danger of veil is thus reduced. The drying is conducted in the usual manner, care being taken not to disturb the plates till they are thoroughly dessicated.

If the calculation as to the amount of silver nitrate necessary to combine with bromide and hydrochloric acid be made, it will be found that there is a considerable excess of silver nitrate in the above emulsion. The organic matter of the preservative is present to give intensity during development.

The development is conducted by formula III. or IV. p. 104. With III. the following proportions :—

No. 1 solution . . .	4 parts
,, 2 ,, . . .	2 parts (1 part in cold weather)
,, 3 ,, . . .	1 part.

These are well mixed immediately before use, and after the plate has been moistened by water are flowed over it. If the exposure has been of right duration the image should immediately appear, in which case the solution should be flowed back into the developing cup, and the detail be allowed to 'come up' by the small quantity remaining in the film. When this is secured another part of No. 3 may be added, and density will gradually be attained. The writer prefers not to give the full density by the alkaline solution, but rather to gain it by the application of the pyrogallic acid intensifier with the silver nitrate solution (see p. 71). If this procedure be adopted the development should be stopped immediately all the detail is visible by reflected light, and the surface should be flooded with a 1 per cent. solution of acetic acid in water. The intensification next proceeds as in the ordinary bath dry-plate processes.

With an under-exposed picture, if the detail does not appear with the above proportions of the alkaline developing solution, a new mixture is made, nearly all of No. 2 solution being omitted. Unless the exposure be very much under-timed, this is usually efficacious. With an over-exposed picture the image will flash out ; the developer must at once be washed off, and a double amount of No. 2 added, or resort may at once be made to the acid intensification.

With formula IV. (p. 105) the following proportions are taken :—

No. 1 solution	1 part
,, 2 ,, ...	9 parts
,, 3 ,, ...	12 parts.

These are well mixed together and applied as if formula III. were in question. The image comes out rapidly, but at first is deficient in density; by applying 6 parts more of No. 3 solution sufficient opacity of image may be gained without having recourse to the acid silver intensification, though, as before, the beauty and delicacy of the image is much enhanced by its employment. An under-exposed picture is developed by adding other 12 parts of No. 3 and ½ part of No. 1. It is not advisable in any circumstance to reduce No. 2 solution to less than 8 parts.

CHAPTER XVII.

WASHED EMULSIONS.

We now come to a class of emulsions which are in great favour at the present time—washed emulsions. There are almost endless varieties of preparation, but experience seems to show that the simpler the formulæ are kept, the more certain are the results. The following is a mode of preparation which has almost invariably given rapid and excellent results, and the writer strongly recommends it.

The plain collodion is prepared as follows:—

Ether, ·730	50 cc.
Alcohol, ·820 to ·830	25 cc.
Zinc Bromide	5 grammes.
Pyroxyline	2·5 to 3·5.

The variation in the amount of pyroxyline is given, as on its quality largely depends the amount which is essential. With ordinary pyroxyline the smaller amount will suffice, whereas, if it be of a short pulverulent class, the larger quantity will be necessary. The writer recommends the ordinary tough pyroxyline, prepared from ordinary cotton previously boiled in strong alkali, and in the strength of

acids given at p. 45. The zinc bromide may be dissolved in the alcohol, with a small amount of water in addition, if found necessary. To the above quantity of zinc bromide should be added about 30 drops of nitric acid, or 1 small drop of bromine. The reason for either of these additions has already been given. If the bromine be employed, care should be taken to estimate the quantity of silver nitrate with which it will combine. This may be conveniently executed by dropping, say 3 drops into 50 cc. of water, and precipitating with a standard solution of silver nitrate, or by taking care to have an excess of silver filtering, washing the precipitate, and gently igniting it, in order to convert the silver bromate into silver bromide, and then weighing it.

When the bromised collodion is perfectly clear from all floating particles, which can be secured by allowing them to settle, or by filtering them through cotton which has been previously well washed and rinsed with alcohol, it is ready for the addition of the silver nitrate. It is well to allow an excess *at least* of $\frac{1}{2}$ per cent. of the silver salt if great sensitiveness is required, otherwise the bromide may be allowed to be slightly in excess. To convert the above amount of zinc bromide into silver bromide would theoretically require 7·56 grammes, but in practice it is found that this amount cannot be depended upon. When nitric acid is used with the zinc bromide it will be found that 8·5 grammes suffice. When the bromine is used the amount required must be subject to experiment. The student may find it convenient to add the silver nitrate solution little by little till he hits the point where an excess commences, and then to add $\frac{1}{2}$ per cent. more of silver nitrate. To ascertain when the excess occurs, a drop of the emulsion, from time to time between the additions of the silver nitrate solution, should be poured on to a glass plate, and a little potassium chromate dropt on to it; a red colouration due to silver chromate shows the slightest excess.

The silver nitrate is dissolved up as in the last process,

and poured in as already described. It may be as well to note that finer-grained emulsion is sometimes made by keeping out half the collodion, adding the whole of the silver little by little, and then stirring in the other half of the collodion.

In order to obtain a maximum sensitiveness, the emulsion should be left for from 24 hours to 60 hours, the time depending much on the kind of pyroxyline employed. If a large batch of emulsion is to be made up, it may be advisable to prepare 50 cc. first, and at the expiration of 24 hours, 48 hours, 60 hours, to wash it as directed below, and test its qualities; and a note should be made of the period at which it seems most sensitive, and at the same time free from fog. It is noteworthy that the washed emulsion usually appears to possess the same qualities as the unwashed. If, therefore, this process of testing be considered too tedious, the emulsion may be tested at intervals in the unwashed state, or, to speak more correctly, after it has been washed after coating the plate. When the emulsion is in a proper state, it should be poured out into a flat dish, and be allowed to set. A gentle agitation with a glass rod causes more surface to be exposed, and the evaporation consequently takes place more rapidly. In a moderately warm room half an hour will generally suffice to render it in a condition fit for the subsequent washing. This may be known by the glass rod separating the gelatinous mass in flaky pieces, which retain their shape after a minute's interval.

The emulsion is next covered with distilled or pure water, and allowed to soak for 2 or 3 minutes, when the liquid is drained off, and the emulsion transferred into a jar, and again covered with water. After stirring well, and allowing a time to elapse (say 15 minutes) in order that the water may penetrate into the interior of the mass, it is again drained off and replaced by fresh water. This washing is continued till the wash water, treated with hydro-

chloric acid, if an excess of silver have been employed, or with silver nitrate solution, if excess of bromide have been employed, shows only a *slight* opalescence. It is important that the washing be done rapidly, as long soaking of the gelatinous emulsion is greatly detrimental to securing density of the image when alkaline development is employed. The reason of this lack of density seems to be due to the fact that some small portion of the precipitated pyroxyline is soluble in water, and that it is this organic substance which causes the silver to be reduced in the film to such a state of subdivision as to cause opacity.

When the washing is complete, the emulsion pellicle is pressed between blotting paper in order to get rid of the greatest part of the water which is occluded in it, and is allowed to dry spontaneously or by the aid of heat.

The first mode of drying is the safer, as it sometimes occurs that the heat of even a water oven, fig. 26, is sufficient to shrivel up the pellicle to such an extent that it becomes very insoluble in a mixture of ether and alcohol. The procedure that the writer recommends is to allow it to become *nearly* dry in the water oven, and then to allow the last remains of water to evaporate spontaneously. A slight quantity of water is not hurtful to the emulsion, and if, after hard pressure with a spatula on a square of the pellicle, there is not sufficient moisture to damp blotting-paper, it may at once be transferred to a bottle to re-dissolve. The bottle employed should be capable of holding twice the amount of solvents that will be used, as space is required for shaking.

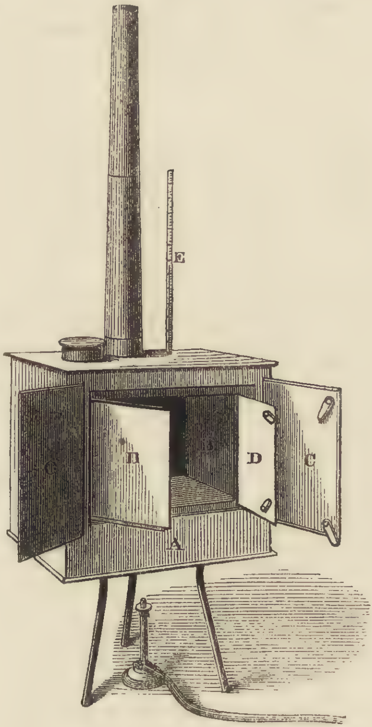
The solvents employed are equal parts of pure ether and absolute alcohol, 100 cc. being employed for every $1\frac{3}{4}$ grammes of pyroxyline employed.

With some pyroxyline the resulting images are deficient in vigour. To correct this, to the first wash water a strong solution of tannin, or salicine, &c., may be added.

A modification of the above emulsion may be prepared by emulsifying with an excess (say 5 grammes) of silver

nitrate, after 15 to 20 drops of strong nitric acid added to each 100 cc. of the collodion. After the addition of the excess of silver nitrate a sufficient quantity of some metallic chloride, such as of cobalt, may be added, in order completely to

FIG. 26.



neutralise that excess of silver, and to leave a slight excess of the soluble chloride. This method is due to Mr. Newton, and in his hands appears to work satisfactorily. The presence of a free chloride is not so destructive of sensitiveness as the free bromide, hence the preference that is given to the

former over the latter for neutralising any excess of silver nitrate. It is often useful to keep the pores of the collodion open by a little resinous matter, such as gum ammoniacum. This gum is very insoluble, and, if employed, a saturated solution of it in alcohol should be prepared, and the resulting varnish should replace the alcohol, employed for re-dissolving the emulsion pellicle. With all the washed emulsion processes the plate is coated as with ordinary collodion and allowed to dry, no preservative being necessary. The dark heat which is radiated from a slab of iron, placed over a spirit lamp or Bunsen burner is recommended by Mr. Woodbury to cause the rapid evaporation of the solvents from the coated plate. The plate must not be exposed to the naked flame from these sources, as the blue colour is sufficiently intense to cause a veil to spread over its surface on development. Washed emulsion plates will keep indefinitely both before and after exposure, as will the emulsion if all excess of silver nitrate be washed away. The exposure necessary is largely dependent on the presence of soluble bromide or chloride and on their quantity. As a rule the plates require half as much exposure again as a wet plate.

The development is conducted as laid down for the previous process, and calls for no especial remark.

CHAPTER XVIII.

THE GELATINO-BROMIDE PROCESS.

In this process we come upon another type of the emulsion processes, and one which in some cases gives excessively rapid plates. The medium used for holding the sensitive salts in suspension is gelatine, which gives very valuable qualities to the image. It seems, however, to be doubtful

whether the emulsion can be prepared with an excess of silver nitrate, without incurring certain subsequent drawbacks. It is better to use a formula which has an excess of bromide, and an emulsion thus prepared will furnish plates which at all events are as rapid as a wet plate. The following is the method of proceeding in preparing the plates, as given by Mr. Kennett :—$\frac{1}{2}$ a kilogramme of Nelson's gelatine is soaked in 3 litres of distilled water, and after it is completely hydrated—known by all hardness having disappeared—the jar containing it is heated till solution is effected. It may be noted here that it has been recommended by the Rev. J. Palmer to substitute mild ale for half the quantity of water, but owing to the saccharine matter in it, a decomposition is apt to set in which destroys the plates when prepared. While the solution is still hot, 280 grammes of potassium bromide are added and thoroughly incorporated ; 380 grammes of silver nitrate are next dissolved in the smallest possible quantity of water, and added, with constant stirring, little by little to the bromised gelatine. This may be done in a subdued light, absolute exclusion from actinic rays being preferable, though not absolutely necessary. All subsequent operations *must*, however, be conducted in the dark room. The emulsion is next poured out into a dish and allowed to set firmly, after which it is cut into strips and washed in a jar with constant changes of water for six hours or more. When the water shows no milkiness on the addition of silver nitrate, it is to be presumed that all the soluble salts, including the excess of potassium bromide, have been washed out. If the gelatine be in very thin layers it may be allowed to dry spontaneously ; the aid of heat is necessary, however, if it be in thicker layers. In this pellicular state it will keep indefinitely. Mr. Kennett has obtained a patent for drying the gelatine emulsion by the aid of heat, and it need scarcely be said that the supply issued in this form is very convenient. In every 100 cc. of water, 9 grammes of the

pellicle may be dissolved, by allowing it to soak and then by applying heat. A plate which has been properly cleaned and then slightly warmed is flowed over with the solution as if with collodion, and, after the gelatine has set, is placed on a level shelf or table to dry. In the last operation failure is most to be apprehended. There is always such a quantity of dust in the air, of greater or less size, that the danger of specks is really great. Perhaps the best method of avoiding dust is to cover the plates with a framework over which is stretched a piece of close muslin; this filters out the larger particles of dust. These covers also have been found effective in preparing gelatine plates for the mechanical printing processes. When the excess of moisture has been evaporated by the air, the plate is finally dried in a drying closet, the operation being accomplished in two or three hours. The exposure required, as already stated, is about equal to that of a wet plate.

The following developing solutions are recommended by Mr. Kennett, of Maddox Street, who prepares these plates commercially:—

1.	Pyrogallic acid	1 gramme
	Distilled water	100 cc.
2.	Potassium bromide . . .	5 grammes
	Distilled water	100 cc.
3.	Potassium bromide . . .	.4 gramme
	Distilled water	1 litre.
4.	Ammonia (·880). . . .	1 part
	Water	16 parts.
5.	Gelatine	4·5 grammes
	Distilled water	1 litre.

The plate is first allowed to soak in No. 3 for five minutes, the temperature being kept about 15° C. To this solution in the dish is next added about 10 per cent. of No. 5, and after thorough soaking the plate is drained. To every 50 cc. of No. 1, 3 cc. of No. 2 and 3 cc. of No. 4 are added, and flowed over the surface. The detail should gradually make its ap-

pearance, and, when well out, more, in equal parts, of Nos. 2 and 4 should be added till sufficient density is obtained. In case this still leaves the 'whites' of the negative deficient in opacity, the ordinary pyrogallic acid intensifying solution (p. 71) may be resorted to. The above development is efficacious when the plates are of the extra rapid kind supplied by Mr. Kennett; if they are prepared exactly as given above, the preliminary soaking in No. 3 and No. 5 should not be carried out, but distilled water should be substituted for them. The fixing solution recommended by Mr. Kennett is the hyposulphite solution (p. 75). The cyanide can be equally well applied. The great secret of success seems to be in keeping the temperature of the washing water at about 15° C., and in giving the plates sufficient soaking previous to applying the developer. The films do not seem to be affected after fixing by ordinary moisture, a change in the structure of gelatine apparently taking place. The image given by this process is generally of an olive green, which is highly adiactinic.

The ordinary yellow glass of the developing room does not cut off sufficient of the actinic rays to afford complete protection against the veiling of these plates; but the light passing through flashed ruby glass is found to be of a sufficiently adiactinic character to be a suitable light in which to conduct the developing operations.

This process is well worthy of trial, particularly where rapidity of exposure is a desideratum.

CHAPTER XIX.

CALOTYPE PROCESS.

HAD the historical order of photographic processes been followed, the calotype process would have been described immediately after the Daguerreotype process, but it seemed more likely that the details of the former would be better understood after a study of the collodion wet and dry processes. The original process which Fox Talbot introduced has been but little improved, and it is therefore given nearly as he described it, modifications being suggested where necessary.

The paper employed should be as tough and grainless as possible, capable, however, of holding sufficient of the sensitive compound to give a body to the image. Good English paper of the consistency of medium Saxe answers every purpose. The great drawback to all papers of the present day seems to be the chance of transparent spots appearing during development, and a consequent damage to the image. What is the chemical nature of these spots is not known, but they can generally be got rid of by brushing a dilute solution of hydrochloric acid over the surface of the paper, and then thoroughly washing off all excess of acid. When dry the paper is ready for impregnating with silver iodide. This last is formed by taking—

No. 1.	Silver nitrate	3 grammes.
	Distilled water	20 cc.
,, 2.	Potassium iodide . . .	3 grammes
	Distilled water	20 cc.

No. 2 is poured into the solution of No. 1 with constant stirring, and a precipitate of silver iodide is formed. The potassium iodide being in slight excess, a certain quantity of the silver iodide is held in solution. The precipitate is

allowed to settle at the bottom of the glass measure (in which we will suppose the two solutions to have been mixed) and the supernatant liquid is poured off, water is again added, and after stirring it is again poured off. This operation of washing is continued some three or four times, or until the soluble potassium nitrate is nearly eliminated.

The silver iodide is next dissolved in a solution of potassium iodide.

Potassium iodide . . .	30 grammes
Water	60 cc.

This is poured on the silver iodide and well stirred. As this quantity will not effect complete solution, crystals of the potassium salt must be added till after much stirring the solution is semi-transparent or milky.

The paper is next cut to a convenient size, and is pinned on a flat board. The solution is applied by a brush of cotton-wool, a good form adapted for the purpose being given in the figure. A is a glass tube of about 20 centimetres long, and above 1 centimetre diameter. A loop of string, B, passes through the tube, across which is placed a thin tuft of cotton wool, C. The loop is then pulled up into the tube, a sufficiency of cotton wool being allowed to remain externally to form the brush. It is advisable first to wash the wool in a weak solution of alkali in water, taking care, however, that none of the alkali remains in the fibre, and that it is thoroughly dried before being used as a brush.

FIG. 27.

The solution is brushed up and down and across the paper, till the whole surface has received a uniform coating of the dissolved iodide. When partially dry the paper is immersed in a dish of distilled water, all air-bubbles being carefully removed from the surface. After soaking for a couple of minutes it is removed to a second dish, and subsequently to a third dish. The water removes the potas-

sium iodide, and leaves a primrose-coloured silver iodide on the surface of the paper. After the washing has been continued two or three hours, the paper is hung up and dried. In this state it is nearly insensitive to light (though not quite so, as the iodide is in the presence of organic matter), and can be stored away between the clean *unprinted* leaves of a book. When required for use, the paper is pinned on to the board as before, and a mixture of the following solutions is brushed over it :—

No. 1.	Silver nitrate	5 grammes
	Glacial acetic acid . . .	8 cc.
	Water	50 cc.

No. 2. Saturated solution of gallic acid in distilled water.

To every cc. of No. 1 add 60 cc. of distilled water, next 1 cc. of No. 2, and finally 30 cc. of distilled water. If the temperature be high, the water must be increased to such an extent that immediate reduction of the silver nitrate may not take place. After well mixing, the solution is applied lightly, but plentifully, to the iodised paper with the cotton-wool brush already described, and all excess blotted off on filtering paper of the purest description. Two sheets are then placed back to back with blotting-paper between them.

The paper is most sensitive in its moist state, but it is also capable of giving pictures when dry, or until the surface of the paper becomes discoloured by a reduction of the gallate of silver. For exposure in the camera a sheet may be placed between two pieces of glass, or the corners may be gummed on to a sheet of glass, the paper taking the position of the collodion film of the ordinary processes. The exposure varies considerably according to the preparation of the paper; and it should always be sufficiently prolonged to give a trace of the sky-line on the undeveloped paper. To develop the picture, the paper must be pinned on the board as before, and equal parts of No. 1 and No. 2 applied, with similar quantities of water as already indicated.

This is applied with the brush, and is continued till the developing action begins to flag. When this is the case, the gallic acid solution, No. 2, is applied very lightly, until the deep shadows begin to dim by transmitted light. The development must now immediately be arrested, otherwise the picture will be veiled.

For an under-exposed picture more of No. 1 should be used than that given, and if over-exposure be feared (indicated by the picture being fairly visible), No. 2 should be in excess. A little consideration of these points will show how development may be equalised in dark parts. An artist in the production of these pictures will be able to produce *a picture* by a little attention to the above details, whilst a mere manipulator would probably produce nothing but an image wanting in delicacy and gradation.

The negative is fixed by immersion in a sodium hyposulphite solution.

Sodium hyposulphite . . .	60 grammes
Water	1 litre.

The fixing being complete, which may be known by a total disappearance of the yellow of the iodide, when the paper is viewed by transmitted light, the picture is washed in abundant changes of water, until all the hyposulphite is thoroughly eliminated. This may be known by applying the test given at p. 151. The washing should take at least three or four hours even in running water.

It may be advisable to call attention to the necessity of the addition of acetic acid to the sensitising solution. This is always advisable in warm climates, as it greatly restrains the reduction of the silver nitrate; the less added, however, the more sensitive the paper will be.

When the paper negative is dry it is ready for waxing. A flat-iron (preferably a box-iron) is heated to such a temperature that it will readily melt white wax. A cake of this substance is brought in contact with the iron, whilst the

latter traverses the paper. The whole of the picture, except the sky, should be rendered translucent by it. The superfluous wax is absorbed by blotting paper placed upon the negative, over which the hot iron is passed. It is a mistake in this last operation to heat the iron too much, over-heating causes the blotting-paper to take up too much of the wax, and leaves the grain of the paper visible. It sometimes happens that yellow spots occur in the whites of the picture. These are generally removable by the application of a dilute solution of hydrochloric acid. It need scarcely be remarked that this entails a thorough washing. The acid must never be applied till all the sodium hyposulphite is thoroughly eliminated, for if any remain in the paper it is decomposed by the acid, and the inevitable result will be a fading of the picture. Further remarks on this subject will be found in the chapter on silver printing.

There are various processes for the production of paper negatives extant, amongst which may be mentioned those of Le Gray, Blanquart-Evrard, and Prichard. That due to Le Gray was at one time a great favourite, its distinguishing feature being that the paper is waxed before being sensitised. The waxed paper is immersed in a solution of potassium iodide and bromide, together with sugar of milk, and after drying is treated with a solution of silver nitrate, acidified with glacial acetic acid. The development is carried on much in the same way as that indicated in the above process, the paper being submerged in the fluid. This last process, perhaps, is better adapted to careless manipulation, than that described above, as all danger of staining the back of the picture is avoided.

The student is recommended at first to use these processes for the production of prints from glass negatives; any representing engravings or maps are, perhaps, the best adapted for a preliminary trial. An easy picture in half tone may next be experimented with, and then a picture in the camera. The advantage of this progressive method of

attaining a knowledge of the process is this: with an ordinary gas burner, any exposure may be given, the time being diminished or increased at will. With the camera, on the other hand, the varying quality of light will often discourage the beginner in his first essays.

The absolute necessity of the cleanliness of all developing cups and dishes, of neat manipulation, and of careful filtration of the solutions, cannot be too strongly insisted upon. A neglect of any one of these will inevitably lead to failure and consequent annoyance. In no negative process is patience and good temper more a *sine quâ non* than in these paper processes.

Calotype is an admirable process for travellers, and is often practised in India at the present day, the amount of chemicals and apparatus necessary for the production of pictures being reduced to a minimum. A few dozen sheets of iodised paper, and a chest containing silver nitrate, gallic acid, and a bottle of acetic acid, are all the necessary chemicals, with the exception of the sodium hyposulphite. A box of scales and weights, the camera and its legs, and a couple of pieces of clean glass of the size of the slide, a few drawing pins, a folding dish, a cotton wool brush-holder, and candle-shade, complete the apparatus.

CHAPTER XX.

SILVER PRINTING.

In the fourth chapter the results of the action of light on silver chloride and organic compounds of silver were shown. In this part it is proposed to treat the subject rather more fully, as silver printing entirely depends upon it.

The student would do well to make the following experiments for himself, as by so doing the rationale of the varia-

tions in the processes will become familiar to him, and many failures will be avoided by a study of the theory.

Take any ordinary paper which contains size of some description, and immerse it in a solution of sodium chloride.

Sodium chloride	1 gramme
Water	50 cc.

Hang it up and allow it to dry, and in non-actinic light (adopting the manipulations which will be presently described) float several pieces of convenient dimensions on a solution of silver nitrate for three minutes.

Silver nitrate	5 grammes
Water	50 cc.

When dry to the touch, place one of these pieces under a negative in a printing frame, and expose it to the action of the sunlight; after a few seconds open the frame in a subdued light, and note the result. The parts acted upon by light will have a violet tint, and if ammonia be applied to a portion of the darkened paper it will be found that the image almost entirely disappears. For reasons already given this will indicate that the silver chloride is dissolved. Allow further play of sunlight, say for a couple of minutes, and again note the result. It will be found that the image is much redder in colour, and that ammonia fails to remove all the colouration. From this we infer that the organic compound formed by the size of the paper and the silver nitrate is acted upon. Next take another sheet of the same paper and wash out all excess of silver nitrate, and expose under a negative, and examine the print at the same intervals as before. It will be found that the short exposure produces hardly any perceptible darkening, whilst with the longer it is much less than in the previous experiment. From the results of experiments already detailed in the fourth chapter, it will be seen that the absence of silver nitrate prevents the darkening of the silver chloride, and that the organic com-

pound is the more impressionable. A minute examination of the image will also show that there is a spotted irregular appearance in the darkest parts. There is an easy theoretical explanation of this. The chlorine liberated from the darkening silver chloride is taken up by the organic compound, bleaching it to a certain extent, forming white chloride of silver, which in its turn is capable of being acted upon by light. Experiments with similarly washed paper will show that, though the first darkening is much slower than in the unwashed paper, yet the action of the former approaches more nearly the rapidity of the latter, as the organic silver oxide, which is greedy of chlorine, is formed. Next, fix these paper images by immersion in the bath of sodium hyposulphite, as given at a subsequent portion of this chapter. Both prints will assume a foxy-red colour, that containing no free silver nitrate losing least in depth. The reason will be apparent. The silver subchloride, Ag_2Cl, formed is soluble as far as one atom of silver and one atom of chlorine is concerned ($AgCl$), leaving behind one atom of metallic silver. Since it is only the surface of a particle of silver chloride that is blackened, the darkening of the compound is in itself a protection from the penetration of light into it. It can be shown that the depth to which such penetration can take place with ordinary exposure is very superficial, hence the metallic silver left behind must be exceedingly minute; so small is it indeed that the most delicate balances are too coarse to weigh it. It may be of interest to note an experiment which was carried out to test this. One thousand square centimetres of a glass plate were coated with a layer of silver chloride held *in situ* by inert collodion, and exposed to sunlight in the presence of an excess of silver for five minutes. The original amount of chloride was 102 centigrammes, and after fixing in the bath the metallic deposit was dissolved off in nitric acid, and estimated volumetrically, and found to give only 55 milligrammes of metallic silver.

The organic substances employed in printing may now briefly be considered. Albumen undoubtedly comes first, owing to the properties it possesses of giving a good tone when converted into albuminate of silver if in contact with silver chloride and excess of silver nitrate, and also on account of its insolubility after coagulation.

The formula for albumen is taken as $C_{72}H_{108}N_{18}SO_{22}$, though it can scarcely be said to be established with any certainty. Albumen coagulates in the presence of nitric acid, and also at 65° C. It is precipitated, but not coagulated by alcohol. It combines with the metals, prominent amongst which is the compound it forms with silver. Silver albuminate is white, turning a dark red-brick colour in the presence of white or other actinic lights. The change is speedily effected, and, like other organic compounds of silver, is not dissolved by ammonia after darkening, though the addition of an alkali speedily dissolves the white albuminate. This alone prevents the adoption of an alkaline solution of silver, such as the ammonio-nitrate of silver for sensitising paper coated with this and some soluble chloride, as the effect would be simply to dissolve it. Gelatine, which is the size used in some papers, combines with silver, and forms a red tint on exposure to light; owing to its colour, and the greater difficulty of toning, it is not usually employed in printing operations. Starch ($C_9H_{10}O_5$) forms a compound with silver, which on exposure to light darkens to a more violet colour than either of the preceding. It is largely used in sizing paper, and it is consequently necessary to note this colour.

From the foregoing remarks it will be seen that all the bodies which are employed in sizing ordinary paper will combine with silver, but there are other reasons why albumen is that which is usually employed. Its adoption is due to the fact that it remains on the surface of paper, forming a smooth and thin layer, which is capable of holding *in situ* the different chlorides, and that on the application of silver

nitrate this delicate film is converted into an organic salt of silver together with the silver chloride. In all printing operations one point is a desideratum, viz., that the image should be on the surface of the paper and not sunk into it. The importance of this may be tested by sensitising albumenised paper on the reverse side, and endeavouring to obtain a print on the albumen surface in the ordinary manner. It will be found that the image will appear feeble by reflected light, though by transmitted light it will appear well-defined and dense. When albumen is used fresh, and in a slightly alkaline condition, the resulting print possesses greater stability than any of the foregoing substances; as regards delicacy of image it cannot be surpassed. Unfortunately albumen is most easily applied to the surface of paper when slightly acid, the acidity being due to decomposition, and the resulting compounds formed are more liable to change.

It may be asked, why not print in pure silver chloride alone, held *in situ* by some vehicle, such as collodion? This is not impossible though impracticable, as the reduction of silver chloride by the fixing solutions is so great, that the print would be wanting in vigour. With the addition of some organic compound, however, it becomes quite feasible; but then, be it remembered, the depth obtained is due to that organic substance. Thanks to the discovery of Mr. Wharton Simpson, that silver chloride and some organic compounds of silver (amongst which we may name citrate of silver) will emulsify in collodion, prints are readily obtained by the collodio-chloride, and possess a beauty which cannot be surpassed. In the next chapter this process will be described; merely mentioning *en passant*, that in this process, as in any other in which printing on silver chloride takes place, an excess of silver nitrate is essential.

The colour of prints obtained is always objectionable if fixed directly after taking out of the printing frame; and resort is had to an operation called toning to render it more

pleasing. This toning may consist of gilding the silver image, platinising it, or substituting some other metal for it. The colour of the silver print when appearing through this other metal may give a pleasing tint, or it may fail to do so, according to the extent to which the operation is carried. It will be seen in the practical instructions in printing, that the picture is more or less washed in water before toning. By immersion in water, the violet-coloured image becomes of a red colour: to what this change is due is rather uncertain. It has been held that it is due to the water dissolving a certain part of the silver oxide. It may be due to a different compound being formed by the combination of water with the altered compound, but this is doubtful. In order to tone the picture, certain solutions of gold, platinum, or other metals are made, and the print immersed in them; the first of these metals, in the shape of gold trichloride, is that usually employed. It is, therefore, proposed chiefly to confine the remarks on toning to that process in which that metal is principally employed. The gold trichloride has the formula $AuCl_3$, which is a fairly stable compound. If its temperature be raised to 170° C. it becomes decomposed, a pale yellow and insoluble powder, gold chloride, $AuCl$, resulting, chlorine being evolved. When the former salt of gold is mixed with a solution of silver nitrate, the chlorine leaves the gold to form silver chloride, and the latter salt of gold is formed. Acetates, as also the carbonates of the alkalis, are capable of precipitating gold from a neutral solution in the presence of any disturbing cause—such as organic matter.

It will be seen from the formulæ given for toning solutions p. 148, that one contains chloride of lime, and as an example of one kind of toning this one will be considered. If a print, so thoroughly washed that all excess of silver nitrate is eliminated, be immersed in this solution, it will be found that the gold deposits very slowly, and that the image becomes feeble and spotted in appearance, whereas with a

print in which the excess of silver nitrate has been but partially removed, the toning or gilding action takes place much more readily.

Chloride of lime is a mixture of calcium chloride ($CaCl_2$) with calcium hypochlorite ($CaCl_2O_2$) being made by passing chlorine over calcium hydroxide, or common slaked lime.

$$\begin{array}{ccccccccc} \text{Calcium hydrate} & + & \text{Chlorine} & = & \text{Water} & + & \text{Calcium chloride} & + & \text{Calcium hypochlorite} \\ 2\,CaH_2O & + & 2\,Cl_2 & = & 2\,H_2O & + & CaCl_2 & + & CaCl_2O_2 \end{array}$$

Now gold trichloride, when uncombined with an alkali, is generally in an acid condition, due to the presence of hydrochloric acid, and in order to neutralise this, calcium carbonate forms part of the toning bath. On immersing the silver print the equilibrium is disturbed, and the gold begins to deposit; and, consequently, chlorine is liberated. In the directions for use of the toning bath it is stated that the solution should be made with hot water if required for immediate use, whilst if made with cold it must stand twenty-four hours. This causes a certain quantity of the hypochlorous acid to be evolved, and leaves a small portion of calcium hydrate in solution.

In the case of the thoroughly washed print, the chlorine attacks the silver subchloride or the organic silver oxide, and forms the white silver chloride; for, be it remarked, the gold which is situated nearest the printed surface is first reduced, and the image is therefore in close proximity to the chlorine, and readily attackable by it. At the same time the silver oxide and sub-chloride are in proximity to the chloride of lime, which reduces them also to the state of chloride, particularly if it be rich in hypochlorous acid. In the case of the slightly washed print the same action takes place, but we have a new element to deal with. In this case the solution or excess of the silver nitrate held in the pores of the paper gradually becomes diffused to the surface, combines at once with the liberated chlorine, and forms chloride of silver, *but not at the expense of the*

image. It will be noticed in toning operations that this chloride is absolutely formed on the surface of the print, and can be removed by a slight rub with the finger. On fixing the print, the silver chloride is in both cases removed ; in the one from the image itself, in the other from the paper. This accounts for the spotted appearance in the one case, and its absence in the other.

To test this theory, the following experiments were undertaken by the writer. A print was thoroughly washed, then immersed in a solution of lead nitrate, and again slightly washed. On applying the chloride of lime toning bath, the print quickly changed to a rich brown colour, and, after fixing, had all the qualities of a properly toned print. In this case the lead combined with the chlorine, and acted like the silver nitrate. Another toning bath, consisting of lime water and gold trichloride, was prepared. Two well-washed prints were immersed, and left respectively for three minutes and fifteen minutes ; on the latter a slight deposit of gold was visible, and also a diminution in the depth of the print after fixing. With the former the print was less affected. Prints in which silver nitrate and lead nitrate were present both toned admirably, but rather too rapidly for safety. On examination a trace of hypochlorous acid was found in the toning solution. A slight addition of chloride of lime was next made, and prints in which silver and lead nitrate were present were immersed in the solution ; they toned gradually and regularly. This last experiment, which was confirmed by others, showed that the calcium hypochlorite contained in the chloride of lime, acted as a retarder to the toning operation, as the chlorine contained in hypochlorous acid combined with the silver nitrate equally with that evolved from the precipitating gold. This manifestly would check the deposition of the gold.

Another toning solution used is one made with sodium acetate and gold. In practice it is found that toning takes place most regularly when the print has been previously well

washed. On adding a solution of sodium acetate to silver nitrate, a sparingly soluble silver acetate and sodium nitrate are formed by double decomposition. If then the silver nitrate be present in the print, the greatest portion of the adjacent sodium acetate is decomposed, and sodium nitrate left in its place. The sub-chloride and oxide of silver both seem to be as readily attacked by chlorine as the silver acetate. Hence the chlorine, having nothing at hand to absorb it (sodium nitrate not being able to do so), attacks the silver of the print and produces the bleaching action already referred to. When all the free silver nitrate, however, is washed away, the conditions are changed ; the sodium acetate will absorb chlorine, and form a chloracetate and hydrochloric acid, as indicated in the following equation :—

$$\underset{\text{trichloride}}{\text{Gold}} + \underset{\text{acetate}}{\text{Sodium}} = \text{Gold} + \underset{\text{acetate}}{\text{Sodium trichlor-}} + \underset{\text{acid}}{\text{Hydrochloric}}$$

$$2\,AuCl_3 + NaC_2H_3O_2 = 2\,Au + NaC_2Cl_3O_2 + 3\,HCl.$$

Eventually an evidence of this reaction may be traced in the fact that the solution becomes acid, and refuses to tone.

The foregoing experiments exemplify the following laws :—

(1.) That a neutral solution of the gold toning bath is necessary.

(2.) That some active soluble chlorine absorbent must be present, either in the print or in the solution.

(3.) That when the affinity of the absorbent for chlorine is violent its action must be retarded.

In considering any toning solution, these three qualifications must be taken into account, and if one of them be violated, a perfect print must not be expected.

The theory of fixing prints is the same as already indicated at page 74, and need scarcely be touched upon. The reason why potassium cyanide cannot be usefully employed as a fixing agent has been already shown to be due to

the fact that the organic oxide of silver is soluble in its solution. It must be strongly impressed upon the student that two forms of double hyposulphites of silver and sodium are formed, one of which is soluble and the other insoluble, see p. 74. The soluble form undergoes a change in light, which renders it insoluble; hence fixing the print in daylight should be avoided.

When prints are immersed in a solution of sodium hyposulphite, a certain portion of this salt is combined with the double salt of silver formed. Every print immersed therefore leaves a smaller quantity of the uncombined sodium hyposulphite in solution; and since the double salt of silver and sodium is soluble in the uncombined hyposulphite, it follows that care must be taken not to fix too large an area of print in the same solution, otherwise the insoluble salt will be formed in the pictures. The effect of this is seen in the fading of prints. No amount of washing will eliminate this insoluble form. The acid vapours to be found in the air will decompose it, and cause a liberation of sulphur compounds, which gradually bleach the black portions of the image, and give the whites a jaundiced appearance.

Even where the soluble double hyposulphite has been formed, washing the prints in a thorough manner is essential for permanency, for any trace of it will decompose in a similar manner, as will also the sodium hyposulphite itself. In the writer's opinion the prints should be immersed in two separate solutions of the sodium hyposulphite; the first will form the necessary soluble salt, and the latter will cause it almost entirely to disappear, all traces being subsequently eliminated by the washing water. Some American writers have proposed to shorten the washing of the print by a final immersion in a solution of iodine, tetrathionate being formed; the following reaction would be as follows:—

$$\begin{array}{ccccccc} \text{Sodium hyposulphite} & + & \text{Iodine} & = & \text{Sodium tetrathionate} & + & \text{Sodium iodide} \\ 2\,Na_2S_2O_3 & + & I_2 & = & Na\,S_4O_6 & + & 2\,NaI. \end{array}$$

Both these salts are soluble in water, but less so than the sodium hyposulphite, and the tetrathionate appears to be more readily decomposed. If a silver compound be present with the hyposulphite, the same reaction apparently takes place, though an exact analysis of it has not as yet been undertaken. The quality of the washing water is important —it should if possible be rain water, otherwise pure spring water, to which a little alkali should be added for the first washing. This renders the elimination of the soluble salts more complete.

The causes of instability in a print are as yet imperfectly recognised; and, owing to the want of chemical knowledge on the part of some photographers, the fading has assumed a more mysterious aspect than is warranted. Take the case of the acetate toning solution. It has been shown that it becomes acid, and the prints are often taken direct from this bath to the hyposulphite solution. An acid immediately commences to decompose the latter, and fading necessarily results. Washing between each operation should be insisted upon, and then the chances of fading are reduced to a minimum.

Sometimes it is convenient only partially to print a picture on paper and then to develop in a similar manner to that employed in the calotype picture. The theory is the same, and the manipulations are the same. The advantages obtained by this method of production are more than counterbalanced by the defective tone they usually take, and the lack of purity in the whites. The reason of the difference of tone is accounted for by the fact that the metallic silver preponderates so largely over the organic oxide. The blending of the colour of the latter with that of the precipitated gold is the charm which exists in the ordinary print on albuminised paper. For some purposes the cold tone usually produced does not signify, and then the developing process may be found useful.

CHAPTER XXI.

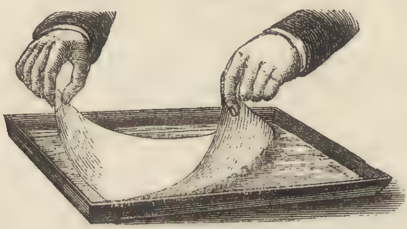
MANIPULATIONS IN SILVER PRINTING.

THE papers employed in silver printing are known as Saxe and Rive, the former being suitable for large pictures, whilst the latter are preferable for smaller sizes. The following formula may be used for the albumen solution, with which to coat the paper :—

Ammonium chloride . . .	10 grammes
Spirits of wine	15 cc.
Water	135 cc.
Albumen	450 cc.

The first three are thoroughly mixed, and the albumen, derived from the whites of eggs, is gradually added to the solution. Perhaps the simplest way of effecting solution and perfect mixture is to half fill a bottle with the albumen, and then to add a fair supply of roughly powdered glass. Shaking the bottle will cause the flocculent matter to be

FIG. 28.



broken up, and leave it in a state ready for filtering through sponge or well-washed tow. The paper, having been cut into sheets of convenient size, is floated on the fluid, contained in a dish, the hands grasping its two opposite corners. The convex surface of the paper thus formed is first brought in contact with the solution. As the hands are

drawn apart, the paper pushes out all air-bubbles before it, and at length lies in perfect contact with the solution. It is a wise precaution to take, however, to raise the paper from one corner, to make certain of the absence of all air-bubbles, and then to allow it to remain at rest on the solution for a minute. It is next removed, and hung on a line to dry, being held by a couple of American clips, or thrown over a stretched cord. This last plan is apt to cause markings, though it is probably necessary when large sheets of paper are manipulated, owing to their tendency to tear if only suspended by two corners. When dry the paper will not be flat, and should therefore be rolled and put away between flat boards. When a print having a dull surface is required, the following formula is sometimes used :—

Ammonium chloride . . .	6 grammes
Gelatine	·6 gramme
Water	300 cc.

The gelatine is first dissolved in hot water, and then the remaining salt added. The paper is floated for three minutes on this solution.

Another mode of producing a dull surface, and which is very effective, is to use resinised paper. The annexed formula is workable, and is due to Mr. H. Cooper, jun. :—

Frankincense	1 gramme
Mastic	·8 gramme
Calcium chloride .	from ·5 to 1 gramme
Alcohol	45 cc.

Good Rive paper is immersed in this solution for half a minute, after which it is ready for floating on a moderately strong sensitising bath.

The Sensitising Bath.

When a paper is weakly salted, say, having half the amount of chloride given in the formula for albumenising paper, a weak sensitising bath is usually employed, whereas

with paper strongly salted, or for the resinised paper, one somewhat stronger is necessary. The following formulæ will show what the extreme strengths of solution should be :—

Silver nitrate	6 grammes
Water	100 cc.

and

Silver nitrate	15 grammes
Water	100 cc.

The paper is floated on either of these solutions in the manner given for albumenising paper, the time of contact varying from three minutes in hot to five minutes in cold weather. It should be removed slowly from the sensitising bath to prevent waste of solution, and when hung up to dry by an American clip in the dark room, the drainings should be collected by attaching a slip of blotting-paper to the bottom corner. It is always advisable to have one corner lower than the others, as the sensitising solution thus drains more equally away.

In order to preserve sensitised paper from colouration due to the decomposition of the organic salt of silver, it may be placed between sheets of blotting-paper impregnated with sodium carbonate. Other devices have been adopted for the same purpose; descriptions of them will be found in the various manuals.

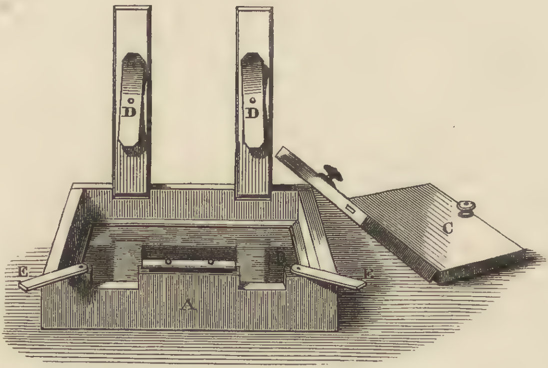
Printing the Picture.

Printing operations are rarely carried on in the same temperature and state of atmospheric moisture as those in which the paper is dried; hence it is advisable to allow the paper to assume the conditions of the former before rigidly confining in the frame. The fact that paper expands in moist air at once shows that the dimensions of a photograph can never be relied upon as being accurate. Measurements have shown that a drawing, for instance, will vary as much as 1 per

cent. in certain conditions of the atmosphere. The same remark applies to plans printed in the ordinary lithographic press; the scale is never correct except under fixed conditions.

The negative should be placed in the printing frame with the varnished side next the paper. A convenient form of frame, and one which is usually employed by photographers, is shown in the diagram. B is a sheet of thick plate-glass, which rests in a frame, A. The negative is placed on the glass, the sheet of paper over it, then a smooth

FIG. 29.



felt pad, and over this a back, C, hinged in the centre. Two cross-bars, D D, to which are affixed springs, cause the back to press on the pad, and are held in position as shown by E E. The use of the hinged back is to allow the print to be examined when required. During such an examination one of the catches E is loosened, and the portion of the picture beneath one half of the back can be inspected without any danger of the relative position of the paper and the negative being changed. The depth of the print is an important point to attend to. It must be remembered that much of the apparent vigour is lost in

the subsequent operations of toning and fixing, and due allowance must be made for this. It requires considerable practice to judge correctly of the proper depth, and no fixed rule can be given, so much depending on the relative proportions of the chloride to the organic compound of silver, and on the nature of the toning bath. Much might be said about the artistic manipulation of prints, but it hardly enters into the scope of this work, though some hints will be given in the chapter on the picture.

Toning.

The following toning baths may be considered as standards :—

I.

Gold trichloride	·25 gramme
Chloride of lime	·25 gramme
Chalk (precipitated)	1 teaspoonful
Water	1 litre.

The water should be boiling if the solution be required to be used at once, otherwise it should stand in an uncorked bottle for twenty-four hours.

II.

Gold trichloride	·25 gramme
Sodium acetate	7 grammes
Water	1 litre.

This should be mixed a day before being used. Before toning the solutions should be filtered in a clean dish slightly warmed, if the weather be cold. The prints are placed in water of about 15° C., and the washing continued as indicated in the last chapter, according to the toning bath employed. They are then immersed in the toning solution three or four at a time, and the dish is kept in constant motion, so as to allow an equal toning action throughout. It is likewise essential that no two prints should stick together, for the same reason. According to the colour

of the print desired, so must the continuation of the toning action be regulated. If a rich chestnut brown be required, but very little apparent change in the colour of the print is necessary, whereas if an engraving black tone is sought, the action must be continued till the image is decidedly blue. It is not to be inferred that these rules are absolute in every case; so much depends on the sizing of the paper and on the amount of chloride present that they are not applicable in all cases, but with Saxe paper, prepared as given in the foregoing formulæ, they will hold good.

Fixing the Print.

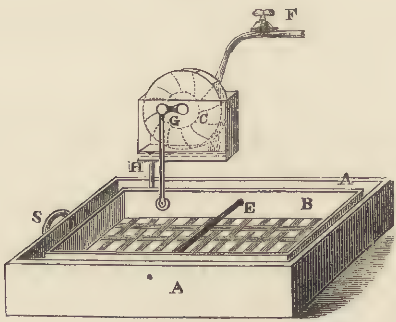
The fixing solution is made up as follows :—

Sodium hyposulphite . . .	200 grammes
Water	1 litre.

Between toning and fixing it is essential that the prints should be well washed. The necessity of this may be understood by referring to p. 141. It has been sometimes recommended to acidify the washing water, but the proposer of this plan can have had no thought of the danger to the permanency of the prints which he thereby introduced; an acid at once begins the decomposition of the hyposulphite. The writer strongly urges the necessity of a strongly alkaline condition of this bath, and in practice he adds 50 cc. of strong ammonium hydrate to it when fixing prints. Mr. J. Spiller was the first to point out the use of ammonium carbonate in the solution; he showed that it dissolved out a certain compound left in the whites of the picture, which otherwise was insoluble, and which readily decomposed under atmospheric action. The pictures should be immersed in the solution for ten or fifteen minutes, the time varying according to the thickness of the paper; they should then be washed (unless they be placed in a second solution of hyposulphite as already suggested), rapidly at first and afterwards more slowly. Perhaps the best way of eliminating the greater part of the

hyposulphite is to place the prints in a large tub of water, which is kept in motion, and after five minutes' washing to place them in a smaller quantity of water. After this they may be removed to a washing trough, where the water will be changed several times an hour. The accompanying idea of a washing trough may prove useful. It is one which was designed and is employed by Mr. England, and has

FIG. 30.



answered well the purpose for which it is intended. A is a trough, at the side of which is a syphon, S, the inside leg reaching to within 2 or 3 millimetres of the bottom, the bend of which is a little below the top of the trough. B is a cradle, pivoted on a rod, E, which passes through the sides of A as shown. C is a water-wheel attached to the wall on to which a gentle stream of water from the tap, F, plays. G is a small arm attached to the axle of the wheel, having a rod suspended from it, which is attached to the cradle, B. As the wheel slowly turns the rod is raised, and the prints are caused to move about in the water. The water runs into the trough through the pipe, H, and when it reaches the top of syphon pipe, the trough gradually empties itself, leaving the prints on the gutta-percha strips which form the bottom of the cradle. It will be seen that the supply of water must always be rather less than that

which the syphon is capable of carrying away. A useful addition to the trough is a horizontal pipe attached to the well of the wheel, moving from side to side by the motion of the wheel, and thus distributing the entering water over the surface of the prints by means of a fine rose. This prevents the chance of any of the prints getting surface-dry, which sometimes happens. In a trough of this description twelve hours suffice to ensure the total removal of the hyposulphite. Should this mode of washing be inapplicable, the prints may be placed in dishes, changing the water every quarter of an hour for the first hour, and every half-hour subsequently for six hours. If during this time they are well sponged twice or three times with a soft sponge, it will be found on applying one of the following tests that the hyposulphite is eliminated.

The first test is based on the reaction of iodine with sodium hyposulphite, shown at p. 142. Take a small piece of starch the size of a pea, powder it and boil it in 10 cc. of water, till a clear solution is obtained; add 5 cc. of a saturated solution of iodine in alcohol to the clear liquid. A dark blue colour due to starch iodide will now be apparent. Drop 2 drops of the solution into two clean test-tubes, and fill up one with distilled water, and the other with the water to be tested. A faint blue colour should be perceptible in the first test-tube, whilst the presence of hyposulphite in the other will be shown by the total absence of colour. The contents of the two solutions in the test-tubes can be best compared by placing a piece of white paper behind them and examining them by reflected light. The sodium hyposulphite may not be found in the washing water, yet a trace may remain in the prints. If a very weak solution of iodine be brushed across the back of a print, the absence of all colour will indicate the presence of the hyposulphite. One selected out of a batch of prints may thus be tested, though it is rarely necessary, if the water indicates that the washing has been thoroughly effected.

The dishes that are used for holding the fixing solutions must in no case be employed for any other purpose. The material of which they are made should be, if possible, glass or porcelain, and never tin or zinc.

The defects in prints due to defective manipulation and not to want of artistic skill are but few in number. Red marks that repel the toning solution can usually be traced to contact with hot and moist fingers. A red tone after fixing is due to an insufficient deposit of gold, and a blue tone to an excessive deposit. The whites may appear yellow through the fixing solution being of insufficient strength, or through paper being used when the sensitive surface shows signs of discolouring through too long keeping. The general cause of the fading of prints has already been detailed.

CHAPTER XXII.

COLLODIO-CHLORIDE PROCESS.

THIS process is intended to be employed for printing on glass or paper, and for permanent silver prints nothing better can be desired. The following is a formula which is taken from the published process of Mr. Wharton Simpson:—

No. 1.	Silver nitrate	4 grammes
	Water	4 cc.
No. 2.	Strontium chloride . .	4 grammes
	Alcohol	60 cc.
No. 3.	Sodium citrate	5·5 grammes
	Alcohol	60 cc.

To every 50 cc. of plain collodion, 1 cc. of No. 1 is added, being previously mixed with 2 cc. of alcohol, in order to prevent precipitation of the pyroxyline. Next 2 cc. of No. 2 are added with constant shaking, and finally 1 cc.

of No. 3. In a quarter of an hour it is fit for use. It will be noted that there is a large excess of silver nitrate present. The amount necessary to combine with the strontium chloride is only ·29 cc. and with the sodium citrate ·18 cc. of silver nitrate; there is, therefore, present more than double the amount of silver nitrate necessary to combine with them. As already shown, this excess is necessary. In practice, particularly when printing on glass, it has been found very difficult to prevent the salts crystallising in the film whilst drying; and in order to overcome this source of annoyance, a method analogous to that of the washed bromide emulsion process may be employed. The above proportions of strontium chloride and sodium citrate may be kept, but the silver nitrate should be reduced to one-half. The plain collodion is made up with half the solvents usually employed to dissolve the pyroxyline, and consequently only half the above quantity is used in mixing the collodio-chloride. After the emulsion is formed it is poured into a dish, allowed to set, well washed, dried, and then dissolved up in the proper proportions of solvents, in the alcohol of which $\frac{1}{2}$ cc. of the silver nitrate solution has previously been added. In this state the collodio-chloride contains the same necessary excess of silver nitrate, but the strontium and sodium nitrates are absent. This diminishes the risk of crystallisation taking place in the film, and with a certain class of pyroxyline this is entirely avoided. The silver citrate supplies the necessary organic matter by which a vigorous image is obtained.

If a glass plate has to be coated with the emulsion, the same directions as those given for coating emulsion plates should be followed, with the addition that it is well to dry the film before a fire, and to print whilst it is still warm. When a paper has to be coated, more difficulty is found. The paper must be strongly sized; ordinary paper allows the collodion to penetrate through its pores, and a mealy appearance is sometimes the result. Arrowroot paper, sup-

plied by most dealers in photographic materials, is perhaps the best kind. Obernetter, of Munich, uses an enamel paper as a support. A similar paper is prepared by coating ordinary paper with a strong solution of gelatine, in which barium sulphate, known as 'Mountain snow,' is mixed. When dry, this gives an impervious skin to the surface of the paper. The paper is pinned on to a board, the edges being turned up 2 or 3 millimetres, and at one corner a spout is formed, from which the collodion is poured off. The emulsion is now applied as if to a glass plate. Some operators find that by fuming the film with the vapour of ammonia, after thorough drying, increased vigour is imparted to the print. In any case this end may be attained by applying a solution of gallic acid and acetate of lead, together with a few drops of a solution of silver nitrate. The print may be toned in any of the ordinary toning baths. Ammonium sulpho-cyanide and gold have been recommended, but the tones thus obtained vary greatly in richness.

For printing on glass, a special printing frame has been designed, but this is not required if the precaution be taken to gum a strip of paper along the corresponding edges of the sensitive plate and of the negative. They may then be separated one from the other with the certainty that they will fall into their original position. The prints are fixed in sodium hyposulphite, made as under:—

Sodium hyposulphite . . .	33 grammes
Water	1 litre.

An immersion of eight minutes in this solution is sufficient.

CHAPTER XXIII.

PRINTING WITH IRON AND URANIUM COMPOUNDS.

As already stated, these processes are not very generally employed for the production of prints, but still they are useful for certain purposes, such as copying engravings, maps, &c., by contact.

Printing Processes with Salts of Iron.

Sir John Herschell investigated the relative sensitiveness of the different salts of iron, and came to the conclusion that the double citrate of iron and ammonia was more readily acted upon by light than any other, whilst after it came the double oxalate of iron and potassium. To produce the former salts, take a weighed quantity of ferrous sulphate, dissolve in water, and boil with nitric acid till it is thoroughly oxidised and in the ferric state; next precipitate with ammonium hydrate, and wash the ferric oxide in warm water to get rid of all the soluble salts. Transfer the washed oxide into a glass beaker and gradually add a solution of citric acid, and warm. When a small trace of ferric oxide remains undissolved, the addition of the citric acid should be stopped. Take the same amount of citric acid already added to the ferric oxide, and carefully neutralise it with ammonium hydrate, testing the operation with litmus-paper. Then mix the two solutions together and evaporate to dryness over the water bath, and when sufficiently concentrated, allow the crystals of the double citrate of iron and ammonium to separate out. After carefully drying between blotting-paper they are ready for use. The double oxalate of iron and potassium may be prepared in a similar manner. When required to render paper sensitive the following proportions should be taken:—

Double citrate of iron and ammonium .	10 grammes
Water (distilled)	100 cc.

This is applied to the paper with a brush, or else the paper may be floated on it. When dry it is exposed beneath a negative from a minute in bright sunshine to a quarter of an hour in diffused light, when it is ready for development; though the image will be barely visible. If a blue picture be required, all that is necessary is that the print should be immersed in a solution of potassium ferri-cyanide. After a few seconds the image will be found perfectly developed. A copious washing in water (in which a little citric acid has first been dissolved for the first washing) will dissolve out all the soluble salts, and leave the blue image unchanged. The theory of this reaction has already been explained in chap. IV., and need not again be discussed. When pictures were developed by this method the process was called cyanotype by Sir J. Herschell.

Instead of developing with the potassium ferri-cyanide, the exposed paper may be immersed in a dilute and *neutral* solution of gold trichloride. The gold gradually deposits on the exposed portions and gives a purple image. This method of producing pictures on an iron salt has been called the chrysotype. The reduction of the gold follows from the fact that the *ferrous* salts are capable of reducing salts of gold to the metallic state when coming in contact with them in solution. In the case of pictures taken by means of the double *oxalate* of iron and ammonium, it is well to add to the gold solution a little neutral ammonium oxalate. The development in this case takes place very rapidly. To fix the pictures they should be immersed in water slightly acidified with hydrochloric acid, and then be thoroughly washed.

An exposed paper prepared with any double salt of iron and ammonium may be developed by floating it on a solution of silver nitrate, to which a trace of gallic acid and acetic acid have been added; the ferrous salt reduces the

silver nitrate, and causes the metallic silver to deposit where the ferrous salt existed. The gallic acid subsequently causes a further reduction of the silver nitrate, and the first deposit of silver attracts the following. An image is thus built up.

Founded on the same reaction pictures may be obtained by means of platinum tetrachloride, mercuric chloride, and potassium dichromate, &c., though greater exposure with these is necessary.

One of the most recent advances in printing with iron salts is due to Mr. W. Willis, junr., and he has made it the subject of a patent.

He floats a paper for a short time on a solution of silver nitrate and dries it. He next brushes over the paper a solution of the double oxalate of potassium and iron, together with a solution of 'chloro-platinite' of potassium. The paper is exposed under a negative, and a feeble image, due to the silver nitrate, is produced. It is then floated on a warm solution of potassium oxalate, and this latter at once reduces the platinum to the metallic state where it is in contact with the ferrous salt (produced by the action of light on the ferric salt), and an image in platinum black is obtained. It was found in practice that, unless a preliminary wash of silver nitrate was given to the paper, the platinum, to form the image, was loosely deposited, and fell back into the solution. By causing a small amount of silver nitrate to be reduced at first to the state of oxide, a nucleus was given, to which the subsequently reduced metal could adhere. To fix these prints, the paper is immersed in sodium hyposulphite, and then in potassium oxalate (the former to remove all traces of the silver nitrate), and afterwards is thoroughly washed in cold water. The prints produced by this process are exceedingly beautiful, and, as platinum black forms the image, they may be considered as being far more permanent than a silver print.

About 1857 Salmon and Garnier brought out a process,

dependent on the fact that the ferrous salt resulting from ferric citrate is more hygroscopic than the ferric citrate itself. Paper coated with the ferric citrate is exposed and then covered over by an impalpable powder, such as plumbago. The surface is then gently breathed upon, and more or less of the powder adheres, approximately in the inverse ratio of the amount of actinic light that has been allowed to fall on it. When sufficient intensity is secured the non-adherent powder is removed by a soft brush. The unaltered citrate is easily washed out of the film, leaving the powder image on the surface of the paper. Better results are obtained when sugar of milk or loaf sugar is mixed with the citrate. The process is not perfect, being defective where half-tones are required; for the reproduction of engravings, however, it is excellent. It will be noticed that, to produce a *positive* picture, a transparent positive reversed as regards right and left must be employed.

Poitevin's Process with Ferric Chloride and Tartaric Acid.

In Poitevin's process another property of a ferric salt is brought to bear, viz., the fact that it makes gelatine insoluble. A 6 per cent. solution of gelatine in water is prepared, with which is mixed any suitable pigment. Paper is floated on it whilst still warm. The paper now presents a uniformly coloured surface. To sensitise the paper it is immersed in a solution of

Ferric chloride	10 parts
Tartaric acid	3 parts
Water , ...	100 parts

and after drying in the dark it is ready for exposure. When exposed to light, the gelatine, which is now insoluble, becomes soluble in hot water. If, therefore, the paper be exposed beneath a positive (reversed as regards right and left), an image may be developed by simple immersion in hot water. The parts which are insoluble remain next the

paper, hence a perfect image may be developed with care. The student should compare this process with the autotype process (p. 162), and note the comparative advantages and disadvantages of the two. It seems to the writer that there is a possibility of a great future development of this process.

Another process due to Poitevin, now known as the powder process, will be given later. Originally salts of iron were employed, but more recently the chromium compounds have been adopted.

Printing with Uranium Salts.

The usual salt of uranium employed for printing processes is the uranic nitrate, and, as has been indicated, this is reduced to the uranous state by the action of light in the presence of organic matter. The following may be taken as a good strength of solution.

Uranic nitrate	40 grammes
Distilled water	250 cc.

The paper should be floated about eight minutes as for sensitising paper in the silver bath. When dry it is ready for exposure, which is somewhat long. To produce a brown picture, float the exposed surface on the following :—

Potassium ferricyanide	1 gramme
Nitric acid	2 drops
Water	250 cc.

In about five minutes the whole of the detail will be visible. After thoroughly washing in slightly acidulated water the image will be fixed.

To produce a grey picture, the exposed paper should be floated on

Silver nitrate	2 grammes
Water	40 cc.
Acetic acid	3 or 4 drops.

The image appears very rapidly, and attains full intensity if the exposure have been sufficiently long. If it be weak, a few drops of a saturated solution of gallic acid added to the above will produce the desired effect. Washing in water will fix the picture, though care should be taken that no chlorides or carbonates are present in it. If any doubt exist as to their presence, sodium hyposulphite must be resorted to. The picture may be toned with gold, platinum, or other salts; as may be desired.

Uranium will also reduce the soluble salts of gold to the metallic state; hence a picture may be developed with these.

A pleasing variety in these prints can be made by mixing with the uranic solution some ferric salt, and developing with the potassium ferricyanide. The resulting tone is richer and quite as permanent. Various other modifications have from time to time been made for the production of different shades of colour in the print.

CHAPTER XXIV.

PRINTING WITH CHROMIUM SALTS.

As already pointed out in chap. IV., p. 32, the dichromates are acted upon by light in the presence of organic matter, and the result is to render such organic matter insoluble in, and non-absorbent of, water. The following experiments may be undertaken.

1st. Let albumenised paper be prepared such as is described at p. 100, preferably omitting the chlorides, &c., and employing only the albumen, and float it on a 6 per cent. solution of potassium dichromate. If the student exposes one of these pieces of paper in a dried state beneath a negative or an engraving, he will find that on soaking it in cold water, all the albumen that has been acted upon by

light will remain insoluble, whilst those protected will readily dissolve. Three or four small pieces of gelatinised paper may next be prepared by brushing over the paper a viscous solution of gelatine, in which is dissolved the above proportion of the dichromate. When dry, they may be fully exposed to light beneath negatives of line engravings. On immersing one of them in cold water, it will be noticed that the protected parts immediately begin to swell, through the absorption of water, whilst those portions unprotected remain unchanged. On immersing another sheet in hot water, the protected gelatine will dissolve away entirely, whilst the rest will remain firmly attached to the surface of the paper. Another sheet of exposed gelatinised paper may next be brushed over with thin, greasy, lithographic ink, and after soaking in cold water, a wet sponge may be applied to remove all the ink that will come away. It will be found that the non-absorbent parts retain the ink, whilst the latter reject it. If portions have been only partially protected, as in the case of what is called a half-tone negative, the ink will be found to adhere thinly on them, owing to the gelatine having become only partially non-absorbent.

One of the earliest processes in which a dichromate was used was that due to Salmon and Garnier, and is similar in principle to the powder processes which are to be described; Poitevin and Talbot were, however, first in the field with practicable application of it.

Swan's process was the first commercially successful, and a brief outline of it may not be uninteresting, as it is still worked by Braun of Dornach. The organic matter employed is gelatine, and it is applied to the surface of paper, after having been coloured with some unalterable pigment, such as lampblack, and sensitised with ammonium dichromate. The prepared paper is next exposed beneath a negative till it is judged sufficiently printed.

The student must now try to realise the work that the light has been performing. Those parts of the gelatine next the

negative will have become insoluble to a depth corresponding to the intensity of light entering, and as there will be but little of the negative which will not allow some light to pass through, it may be considered that the whole of the exterior surface of the gelatine has become insoluble, whilst the soluble portions remain enclosed between the insoluble layer and the surface of the paper. If such a print were immersed in hot water to dissolve away the unaltered gelatine, the viscid solution would remain imprisoned, and no development of the image would be possible. This difficulty Swan overcame by cementing the insoluble surface to paper by a solution of india-rubber. On immersion in hot water the original paper easily strips off, leaving the water free access to the soluble gelatine. When this is completely dissolved away, an image in pigmented gelatine remains on the india-rubbered paper, though reversed as regards left and right. This defect again was overcome in one of two ways—either by using a negative reversed as regards left and right, or by the following procedure. Another piece of paper coated with starch or gelatine, was applied to the image, and allowed to dry in contact. The india-rubbered paper was then moistened with benzine or some other india-rubber solvent, and detached.

It will be well to draw the student's attention to the reason why the portions of the film of gelatine become insoluble to depths corresponding to the intensity of light, instead of becoming only partially insoluble through their whole depth. The light that is chiefly effective in causing the reduction of the dichromate is the blue. Now, since the dichromate is of an orange colour, it is evident that an absorption of the blue will take place, and experiment has shown that a small thickness of gelatine coloured by it will prevent any effective ray being transmitted. In order to cause the reduction of the chromium compound, the amplitude, multiplied by the number of the waves, must be of a certain constant numerical value; if the product falls

short of this constant no change will be effected. On this assumption it will be readily seen that insolubility will take place only to certain depths, depending on the length of exposure and intensity of the light. At the same time it will be seen that it does not necessarily follow that the *whole* of the gelatine or other organic body becomes insoluble to that depth, but that the ratio of soluble to insoluble matter increases as the depth becomes greater. This last point is important, for it seems that the photo-mechanical printing processes are really dependent on it.

In order to obtain perfection in prints formed in gelatine, the image should be dark-coloured and transparent or translucent, in order that the minutest difference in shades may be observable; in other words, the white ground of the picture must play its part in this as in silver printing.

J. R. Johnson was the first to improve upon Swan's process; he found that the insoluble gelatine could be caused by atmospheric pressure to adhere to any impervious surface. This he effected in the following ingenious manner. The undeveloped picture printed in the usual manner on gelatinised paper was immersed in cold water, and allowed to absorb a certain quantity of the fluid, causing the unaltered gelatine to swell slightly. Immediately that the curling of the paper in the water showed that sufficient fluid had been imbibed, he brought the surface of the gelatine and a metal plate nearly in contact, a thin layer of water being allowed to separate them. This water he squeezed out, and the gelatine continuing to swell owing to the fluid remaining in the pores of the paper, a partial vacuum was created between the two surfaces, and the insoluble gelatine was found to adhere firmly to the metal plate. When the picture, so held, was immersed in hot water the paper backing could be stripped off, and development took place on the temporary metallic support. Gelatinised paper applied to the image could then be employed as a final support. In practice it was found that this method of development was liable to

cause a loss of sharpness in the image, owing to the tension of the gelatine. To overcome this, Mr. Sawyer, of the Autotype Company, prepares an insoluble gelatinised paper support, to which the gelatinised paper is caused to adhere by the same means. In this case the support will expand with the image, and the want of sharpness is thus overcome.

It would be impracticable to recount all the various suggestions that have been made for the improvement of the gelatine process. Much ingenuity has been brought to bear on it, and it seems now to have arrived at a state bordering on perfection. Many of the improvements in it have been patented, and thus the working of the process has been in a measure restricted to the licensees of the Autotype Company, to whom most of these patents have been assigned. The manipulation of the autotype process will be described, as it is that which has gained the greatest success.

In regard to the insolubility of dichromated gelatine after exposure to light, a remarkable fact was noticed by the writer. It was found that where the insolubility of the gelatine caused by light had once commenced, it continued in the dark, and that the action was further increased by exposure to what would ordinarily be non-actinic light. This remarkable property has been utilised in the autotype process to diminish exposure; and Marion, of Paris, likewise took advantage of it in a process known as Mariotype. An outline of this process is as follows:—A paper is coated with gelatine, rendered insoluble by alum, and sensitive by potassium dichromate. It is exposed beneath a negative; and a sheet of gelatinised and pigmented paper, which has also been impregnated with potassium dichromate, is brought in contact with it in an unexposed state. The two are kept beneath pressure in the dark for eight or ten hours, and are then withdrawn. The action set up in the impregnated paper by the light is communicated to

the other coloured gelatine, and, as it starts from the bottom surface of this towards the top, the soluble portions are exposed to the solvent action of water, when the paper support is removed. The development takes place in the ordinary manner, and the image is not reversed as regards right and left. The process is not practised to any extent, but is a curious example of a catalectic action started by the impact of light.

All gelatine which has been long in contact with a dichromate, when dried, becomes insoluble after a time without any exposure to light having taken place. The probable cause of this has been shown at p. 32. In hot climates the drawbacks to the use of gelatine in any form are that the ordinary temperature of the water is such as to render it liable not to set, but to remain in solution, and if dried it rapidly becomes insoluble. With care, of course, the want of setting power may be avoided, but there is no doubt that the difficulties of working this process in the tropics are far greater than in a temperate climate such as that of England.

The paper when coated with gelatine and pigment is technically termed carbon tissue, and as such it will be referred to.

Since the original patent of Swan many improvements in the manufacture of the tissue have been made, and the different substances added to the gelatine are only partially known to the public. The Autotype Company, who possess Swan's patent, together with all others which are essential to the right working of the process, supply the tissue at a reasonable rate, and an amateur cannot do better than procure the needful supply from them in preference to making it himself. Should he determine to make it himself, however, the following solution should be prepared :—

Nelson's No. 2 flake gelatine	100 grammes
Sugar (brown)	10 grammes
Honey soap	10 grammes
Glycerine	20 cc.
Water	400 cc.

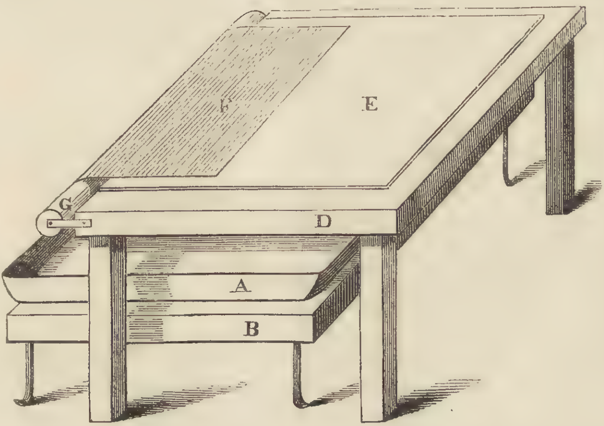
Pigment of a permanent nature is finely ground, and incorporated with a little warm gelatine and glycerine, and then mixed into the above. Aniline dyes may be employed, though some are apt to render the film insoluble, as are also certain kinds of pigments. There are two ways of applying this gelatine solution to paper. A fixed quantity may be taken in a measure and applied to paper which has previously been soaked in warm water, all excess of moisture being blotted off on blotting-paper. The paper in this case is placed on a carefully levelled glass plate, and the proper quantity of fluid poured on and distributed evenly over the surface by means of a glass rod. In cold weather the gelatine will set almost at once, and when firm the paper is hung up to dry. In warm weather iced water may be caused to come in contact with the bottom surface of the glass plate, which will cause the setting to take place rapidly. Rapidity in setting and drying is conducive to sensitiveness, and hence must not be overlooked. The next method is simpler perhaps, and almost as effective.

A porcelain or other dish, A, is placed on a hot-water tin, B, the water being kept at boiling point by a lamp or Bunsen burner. Over the dish is placed a level table, D, at one end of which is a roller, G, that is on a level with the top surface of a glass, E, placed on the table, D. The paper, F, is floated on the warm gelatine solution contained in the dish, drawn through it, seized by the hands and drawn over the roller on to the plate, E, where it is allowed to remain till the gelatine is well set; after which it is hung up by clips to dry. The dish has to be removed each time that paper is floated; if B be lengthened, the dish can be run backwards and forwards in a very simple manner.

In making the tissue a great point is the selection of the paper. It will be found advantageous to use rather a porous kind, not oversized. A wash of ammonium hydrate improves it, as all grease is thereby removed.

Another point to be attended to is the temperature of the gelatine solution. If raised too high, the coating given to the paper becomes too thin, and if allowed to fall too much, the surface becomes uneven. Much practice is required before paper can be evenly coated, and it will even then probably be found inferior to that obtained from the manu-

Fig. 31.



facturers. Air bubbles are a constant source of annoyance, and are with difficulty avoided ; the surface should be well skimmed from them before paper is floated.

The tissue when dry is improved by being rolled in a copper-plate press, though it is not essential if the glycerine added have been sufficient to cause it to remain somewhat limp. Once coating is generally sufficient, though if the white of the paper show through the gelatine and pigment it will be necessary to give it a second coating in the same manner as before.

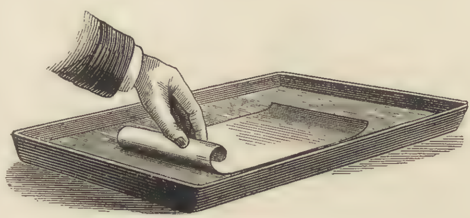
Should it be required to sensitise the gelatine at once, 40 grammes of potassium dichromate should be added to the above.

Whether the tissue be home-made, or be supplied by the Autotype Company, it can be sensitised in a solution of

Potassium dichromate	50 grammes
Water	1 litre.

This solution should not contain free acid, as, if it does, the tissue is liable to become insoluble. This fact has been utilised by Dr. Monckhoven in his method of preparing carbon tissue. In order to float the tissue on the above solution, a dish somewhat larger than the piece to be sensitised

FIG. 32.



is used; and it is coiled up into a small roll, with the gelatinised surface outside. The extreme end of the tissue forming the roll is turned up for a centimetre. In this form the tissue acts as a spring, and will unroll itself if allowed to to do so. Advantage is taken of this. The turned-up end is brought to one side of the dish and dropped on the solution. The hand grasping the roll is gradually unloosed, and the tissue, uncoiling itself, pushes the end which first touched the solution to the further side of the dish, and lies flat on the solution, all chance of air-bubbles clinging to it being thus avoided.

After floating for three minutes the turned-up end is pinned to a lath, by which it is hung up to dry. The dry-

ing room should be well ventilated, and have a constant current of dry air circulating through it in order to cause rapid drying, which is so favourable for sensitiveness. When quite dry the paper is exposed under a negative in the ordinary manner, taking the precaution, however, to leave a small portion at the external edges of the tissue not exposed to light, since this gives greater certainty of adhesion to the metal plate, or other impervious surface, in the subsequent operations. A mask of brown paper placed over the negative effects this. Owing to the colour of the pigment no change of appearance in the tissue will be noticed if examined after exposure. It is therefore necessary to resort to an actinometer, in order to judge of the exposure. The various forms of these instruments will be given in a subsequent chapter (p. 262). It may be noted here, however, that from two to five tints equivalent to the standard tint are requisite in carbon printing.

By adopting the plan of under-exposing, and leaving in the dark, or in non-actinic light, as explained at p. 164, the exposure of course can be materially reduced.

When in a developable state a shallow tin or other dish is filled with water, and a finely-mulled zinc plate is placed at the bottom of it. The plate must have been previously treated with what is known as waxing composition, made as follows :—

Beeswax	3 parts
Yellow resin	3 parts
Oil of turpentine	160 parts

These proportions are not absolute, as the composition of the beeswax varies. 'The resin must be added to the beeswax in such proportions that the gelatine film will remain on the plate without cracking or peeling, even when dried in a hot room, but at the same time will leave the plate readily (when the applied transfer paper has become dry) without the application of any force.' The plate is

first rubbed with a piece of flannel, on which has been smeared a small quantity of the fatty body. All excess of wax, except a very fine layer, which persistently adheres, must be removed by polishing. It is not necessary to wax the plate each time a print is removed, but this must be done whenever the gelatine image shows a tendency to stick to the zinc plate during transferrence to the permanent support. The plates are freed from dirt and greasy matter by the application of a little turpentine, ammonia, or potash.

To attach the gelatine surface to the zinc plate the tissue is immersed face downwards in the water in the dish, and as soon as it begins to curl *upwards*, the zinc plate is lifted out of the water, carrying between it and the surface of the gelatine a layer of water. The plate is then placed on a small low stool (slightly smaller than the zinc plate), and the excess of water squeezed out by means of a squeegee. The squeegee is shown in the annexed figure. It consists of a flat bar of wood, into which is let a piece of india-rubber about $\frac{1}{2}$ centimetre thick and 2 centimetres broad. When all the superfluous water is thus expelled,[1] the gelatine film is allowed two or three minutes to expand, and is then placed in warm water of a temperature of about 40° C.

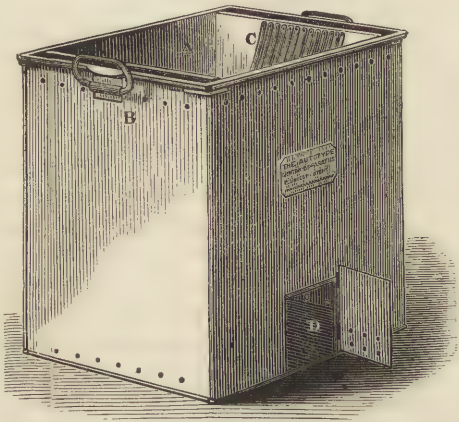
FIG. 33.

The annexed figure shows the developing trough as supplied by the Autotype Company, and it certainly is very convenient for the purpose. A is a trough, fitting into a case B, leaving a space D below, in which a Bunsen burner can be placed, in order to heat the water in A; along the sides of A are grooves, C C, into which the zinc plates slide.

[1] A certain amount of dexterity is required to prevent the paper cockling at the edges, the india-rubber of the squeegee must be brought to bear with considerable pressure on to the surface of the paper, and the strokes made with it should commence from the centre and finish towards the ends.

After half a minute the paper can be removed from the gelatine, and after the water has had free access to it the image begins to develop rapidly, particularly if the plates be moved vertically in the trough. When all the soluble portion is dissolved away, the picture is washed in cold water, and dipped for a second or two in a weak solution of alum and water, and put aside in a rack to dry. Some operators prefer to use a deep dish in which to develop, and

FIG. 34.



doubtless the development is equally readily executed by so doing, but only pictures of a total area less than that of the dish can be developed at one time, whereas with the trough arrangement as many as a dozen pictures can be put in hand at once. For an amateur this is not a matter of great importance.

When the gelatine image is dried, a piece of transfer paper (which is paper coated with gelatine subsequently rendered insoluble in water by alum or other such body) is placed in water of about 60° C., and softened. The picture on the zinc plate is placed in a dish of cold water, and the

softened transfer paper is applied to it in the same manner as was adopted for causing the undeveloped gelatine image to adhere to the zinc plate.

After drying, the picture will peel off from the plate and adhere to the transfer paper. The carbon print is then complete.

The same manipulations, with a few evident modifications, are necessary when the temporary support is pliable.

When a reversed negative is employed, the image may be developed on the final support.

CHAPTER XXV.

WILLIS'S ANILINE PROCESS.

WILLIS'S aniline process may next be briefly described. It is dependent on the action of dichromates on organic matter, though the printed image is given colour by means of aniline. Sized paper is floated in potassium dichromate, to which a little phosphoric acid has been added. It is then exposed beneath a transparent or translucent positive, such as a plan or map, and when the image is perfectly visible, it is exposed to the action of aniline vapour. Aniline salts have the property of striking a green, black, or reddish colour when brought in contact with acidified dichromates ; hence those parts which have not been exposed to light, or have been shielded from it (as is the case with the lines of the positive print), are deeply coloured, the rest of the paper remaining of the faint colour due to the reduced chromium oxide. In developing these prints, aniline is dissolved in spirits of wine, and the mixed vapours are allowed to come in contact with the print. It will at once be evident what an extremely valuable process this is for copying engravings, plans, and tracings. All that is required is a sensitising solution, a sheet of glass to place over the plan, &c. (which,

when exposed, should have its back in contact with the sensitive paper), to keep them in contact, and the sensitised paper. A rough box with a lid, on which can be stretched the printed paper, a basin to contain the aniline solution, and a spirit lamp to warm it, complete the outfit.

The prints can be washed, and are then tolerably permanent.

This process is the subject of a patent secured by the inventor, Mr. W. Willis, and is worked commercially by one establishment. On the expiration of the patent it will no doubt be largely employed by engineers and others for the purposes indicated. There are various modifications of this method of printing by using coloured aniline dyes, such as rosaniline. For some purposes they are useful, but as a rule, they are better for the reproduction of subjects executed in line than for half-tone negatives.

THE POWDER PROCESS.

Reference has already been made to Poitevin's process, in which originally salts of iron were employed to sensitise gelatine, the development being effected by the application of plumbago, or other impalpable powder. The dichromates subsequently were found to answer better than the ferric salts, the development of the prints being somewhat more easy with them. A mixture of gum-arabic, sugar, and a little glycerine, together with a sensitising solution of potassium dichromate, is prepared and poured over a glass plate, or other impervious surface, and allowed to dry in a warm temperature. The plate thus prepared is at once exposed for a few minutes beneath a transparent positive and withdrawn. Those parts acted upon by light will be found to be hygroscopic in the ratio of the time of exposure and intensity of the light. Any impalpable powder brushed over the plate will now be found to adhere to these hygroscopic parts in proportion to the moisture which they hold.

Hence a positive, reversed as regards left and right, will result. When the image is developed it is coated with collodion, and can then be transferred to paper, &c., in an unreversed position. The soluble dichromate will be washed out during the process of transferring. This process is sometimes employed for obtaining images which can be burnt in on glass or enamels. For those who wish to try the process the following formula for the sensitive compound will be found efficient. It is due to Obernetter, of Munich :—

Dextrine	4 parts
White sugar	5 parts
Ammonium dichromate . . .	2 parts
Glycerine	2 to 8 drops for every 100 cc. of water
Water	96 parts

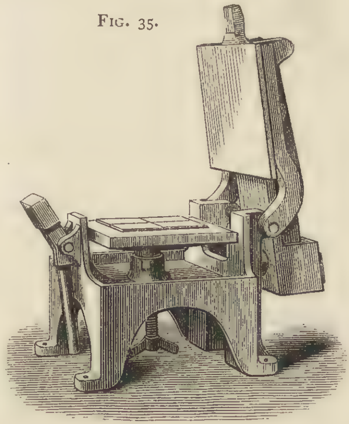
It is sometimes recommended to give the glass plate a preliminary coating of plain collodion. The powder must be very gently applied with a cotton-wool brush or fine camel's-hair brush.

WOODBURYTYPE.

THE Woodburytype process is an exceedingly ingenious method of obtaining a mould of a gelatine print, from which other prints may be obtained. A rather thick film of sensitive gelatine is prepared, resting on a tough film of collodion. This is placed beneath a negative, the collodion side being next the image. It is then exposed to light proceeding from a point, or to sun-light, arranged in such a manner that it always receives the rays in one direction. Uncontrolled diffused light will not do, as, owing to the thickness of the gelatine, the image on development would be ill-defined. When sufficiently printed, the gelatine picture is developed as if it were an autotype print, presenting the image in considerable relief. When dried, the gelatine picture is placed on a perfectly flat metal plate, and a sheet of soft metal (lead, for instance) is pressed on it by means of an

hydraulic press. This latter presenting an exact mould of the former, is then placed in a press made as in accompanying figure. Gelatine is next dissolved in hot water and fine pigment or permanent dye added to it, and the viscous solution thus prepared is poured on to the mould. Paper of a very even texture, and which has been strongly sized, is placed on the top of the pool of liquid gelatine and the top plate of the press, hinged as shown in fig. 35, is brought down on to the mould and firmly locked by the catch, also shown in the same figure, squeezing out the superfluous gelatine. When it is judged that the gelatine has set (which it soon does, owing to its contiguity to a mass of cold metal), the top is raised and the paper, which now bears the picture, is detached. The print is immersed in a solution of alum to render the picture insoluble.

FIG. 35.



The top plate, which is of glass, must be a perfect plane, otherwise the liquid gelatine will not be squeezed out from the portions that are to remain white, and the print will be uneven and mottled. The great relief of the original image is necessary in order to give sufficient intensity to the reproduction, for it must be recollected that the gelatine solution, filling even the greatest depths of the mould, will present but a very thin layer on drying. If the mould were obtained from an ordinary gelatine print there would not be sufficient depth of colour properly to represent the various gradations of shade. The pictures produced by this process are presumably permanent, and can be produced

at a cost but little in excess of the gelatine solution and the paper employed. As can be understood, there are difficulties in the way of producing any large surface which should be represented by pure white, since, however homogeneous a paper may be, it is invariably slightly thicker in some parts than others, and this prevents the glass plate attached to the lid of the press from fulfilling its functions in an absolutely perfect manner.

CHAPTER XXVI.

PHOTO-LITHOGRAPHIC TRANSFERS.

ANOTHER process, to which reference must be made, is that perfected by Colonel De C. Scott, R.E., and Sir Henry James, late Director of the Ordnance Survey of Great Britain. It also is dependent on the *insolubility* of gelatine when treated with a dichromate and exposed to light. It will be described in detail, as it is capable of producing prints in printer's ink, as well as in ink suitable to give a transfer on to zinc or stone. From such transferred prints the original drawing can be reproduced by ordinary surface printing. It may be well to notice the requisites for these transferrable prints. First, the image should be made in an ink which is readily held by a lithographic stone or mulled zinc plate. Secondly, it must be capable of a fair amount of resistance to pressure; that is, it must be tolerably hard and cohesive, otherwise the act of passing a paper holding the image through a lithographic press would cause a spreading of the ink, and a consequent want of sharpness in all the impressions taken from the stone. Thirdly, the ink must be of such a quality that a very thin coating is sufficient to leave a sharp and firm impression on the stone or zinc plate. Fourthly, the paper on which the image is developed must be tough, and not easily torn or stretched. These requisites are fulfilled if the following directions are attended to. The best paper to select is that known as bank

post paper, which is not highly sized. If it be, the sizing should be removed by immersion in boiling water, previous to coating it with the gelatine solution. The solution is prepared according to this formula:—

Potassium dichromate . . .	44 grammes
Gelatine	44 to 66 grammes
Glycerine	2 cc.
Water	1 litre.

The varying quantity of gelatine is due to the fact that some gelatines give much more body to the solution than others. Thus, if fine-cut gelatine be employed it has been found in the writer's experience that the larger quantity will be necessary, whilst if flake gelatine be employed the smaller quantity will usually suffice. The gelatine is of course thoroughly softened in half the above quantity of water, and then the remaining half, in which the dichromate has been dissolved, is added in a boiling state. The solution is poured into a dish, and placed over the hot-water tin, as described at p. 167. A sheet of paper of the proper size is floated on it for three minutes, and then hung up by two corners to dry. This causes the coating to be thicker at the bottom corners than the top, to avoid which resort may be had to the artifice shown in the figure, p. 167. In any case a second coating is required, and this is given in a similar manner. If the paper have been hung up to dry previous to the setting of the gelatine, the opposite corners to those by which the sheet was first suspended should be hung lowest. This secures a fairly even coating. The paper in this condition, even when damp, is slightly sensitive, and therefore it should be dried in a room which only admits non-actinic light. It is exposed in the ordinary manner beneath a negative, which should be of a line engraving, and not in half tint.[1] When the lines appear of a well-defined fawn colour on a yellow ground, the paper should be removed to the dark room for subsequent treatment.

[1] Partial success has been obtained by Sir Henry James in rendering even this latter class of work.

If the object be to make a print to transfer to stone or zinc, the following ink should be prepared (though any lithographic ink will answer fairly well):—

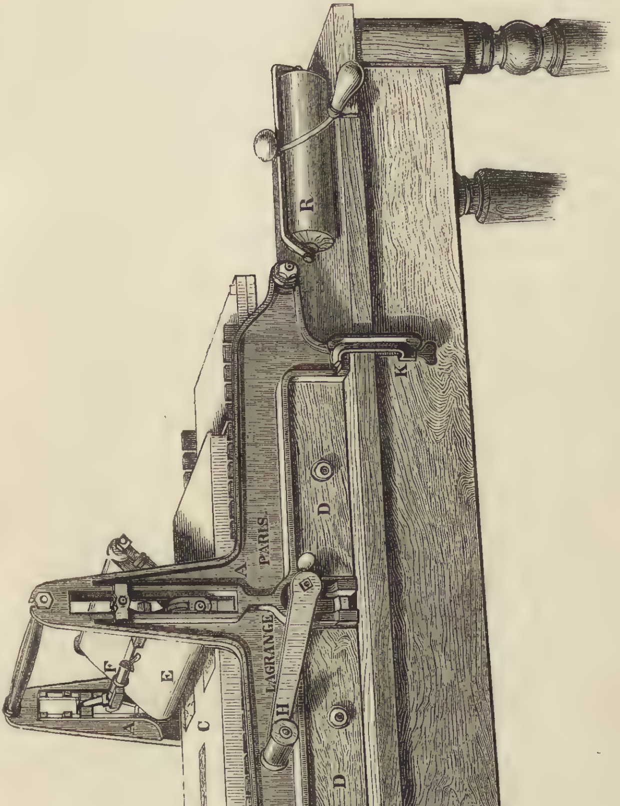
Lithographic printing ink	16 parts by weight
Middle linseed varnish . .	8 parts
Burgundy pitch	6 parts
Palm oil	1 part
White wax	1 part
Bitumen	2 parts

The ink and varnish are first mulled together with a muller, the Burgundy pitch and bitumen are next melted over a clear fire till all water is driven off, the wax next melted, and finally the palm oil. When properly melted they should readily catch fire, which shows that certain gases are being liberated. The ink and varnish are now well stirred into it, and the mixture run into the pots for storage. Should it be desired only to make a single print, the best ordinary chalk lithographic ink may be employed.

Where a lithographic press is available, a fine and even coating of one of these inks is usually given to a stone by means of a lithographic roller, the paper bearing the picture is then placed face downwards on it, and pulled through the press, by which plan a thin coating of ink is given to the entire sheet of paper. In the absence of a press the ink may be rendered liquid with turpentine, and an even film of ink may be given with a fine sponge.

To develop the picture the print is floated *back downwards* on a dish of water, having a temperature of about 50° C., and is allowed to remain on it till the lines are seen as depressions. It is then removed on to a sloping board, and a stream of warm water, of about 70° C., is poured over the surface; the soluble gelatine being in a hydrated condition, is carried away together with the ink that covered it, and the image is left, formed of ink resting on slightly-raised ridges of insoluble gelatine. A very soft sponge dipped in the hot water and applied to the surface aids the development, in fact it can rarely be accom-

Fig. 36.



plished without it; but the most delicate touch is required for this part of the operation, as the ink on the fine lines is very liable to be carried away. The developed print is next washed in cold water, and then hung up to dry. In this state it is ready for transfer to stone or zinc, if transfer ink have been employed. It is beyond the scope of this book to describe the transferring operations: these are described in other works.[1] A very convenient lithographic press, suitable for amateurs, has lately come under the notice of the writer; the figure on the preceding page will give some idea of its form. It is cheap and well adapted for this process, as well as for certain photo-mechanical printing processes.

A A is a cast-iron carriage of the form shown. B is the bed of the press, which is caused to move in the carriage by means of a roller, to which is attached the arm H. D D are drawers containing the necessary plant. C is a lithographic stone, shown in position, and held firm by means of the cross pieces of angle-iron fitting into the slots as shown. E is a substitute for the usual scraper; it consists of a roller, round which, as well as round a smaller roller, is passed a band of flannel. A downward pressure can be given to the roller by an ingeniously devised screw-motion, F, which, whilst giving the necessary pressure, yet causes it to take the natural bearing of the stone or plate. K K are the clamps by which it can be attached to a table, and R is the roller supplied for inking it. With this machine the impressions pulled are excellent, and it is very portable.

Plates made of composition similar to solder are supplied by the manufacturer. They are excessively sensitive to greasy ink, and a number of impressions can be pulled off without clogging the work. To clean these plates all that is required is to wash out the old work with a solution of caustic potash, and then to scour the surface with fine

[1] *Instruction in Photography*, published by Messrs. Piper & Carter; or in Sir Henry James' work, published by Messrs. Longmans.

emery powder. A dilute solution of acid is poured over the plate, and after washing under the tap, and gently warming, it is ready to receive a transfer.

Should only one copy of the picture be required, the print, which should in that case have been printed in lithographic ink, is placed in a copying, lithographic, or typographic press, face up, and a slightly damped piece of white or other paper placed over it. When the pressure is brought to bear, the ink is retained by the latter, and a good impression is thus obtained. This method has been named by Sir H. James as the papyrograph. It must not be mistaken for another process, used for copying letters or circulars, and known by the same name.

Various modifications of this process have from time to time been proposed, such as coating the gelatine with albumen, but in the writer's experience, when a picture is to be obtained by *dissolving away* the gelatine, no better process than the above can be used.

CHAPTER XXVII.

PHOTO-ENGRAVING AND RELIEF PROCESSES.

NIÉPCE'S process, it will be recollected, was founded on the fact that bitumen of Judæa, when exposed to light, became insoluble in its ordinary solvents if partially saturated. Silver plates were coated with bitumen, and after exposure the unaltered portions were dissolved away and iodine applied. The remaining bitumen was then removed, and the image was consequently formed of metallic silver on a ground of silver iodide. Had Niépce removed the iodide by any proper solvent, he would have obtained a plate slightly engraved. Most of the present processes for photographically obtaining relief blocks, and also engraved plates, are based on the same principle as Niépce's;

in fact, there is very little departure from his mode of working until the biting-in commences. The student must distinguish between a relief and an engraved plate. The former is intended to be printed in the ordinary printing press, the portions representing the lines of the sketch being raised as in a wood-cut, whilst with the latter they are in depression. From the nature of the processes to be described it will be seen that the objects to be copied must be drawings in lines and not in half-tint, and up to the present time there is no process of which the details are published, which is capable of giving a good print either from an engraved plate or from a relief block, preserving the proper gradations in light and shade. Secret processes, however, there are, which furnish excellent results : some of these will be mentioned at the end of the chapter. An outline of a successful process for the production of either a relief block or an engraved plate will now be given.

A plate is coated with a thin film of asphaltum or bitumen of Judæa, dissolved in chloroform or other convenient solvent, and after drying it is ready for exposure beneath a subject. If an engraved plate be required, the parts that have to be bitten in are the lines ; hence those portions must be protected from the action of light, since in order to lay the surface of the metal bare they should be covered with the soluble asphaltum. In taking a print from an engraved plate, the latter is reversed as regards left and right, therefore it is evident that a *reversed positive* should be employed, from which to print on the metal plate. For the production of a relief block, by similar reasoning it will be found that an *ordinary* unreversed *negative* picture is required, as it is from its nature reversed as regards right and left. Whether a positive or a negative be employed, the opacity should be extreme on those portions which are to protect the sensitive layer from light. Such a positive or negative is placed in contact with the plate, and exposure given till it is judged that sufficient insolubility is

given to the exposed portions. The soluble portions are then dissolved away by a solvent which is nearly saturated with the asphaltum. If the manipulations have succeeded, the metal should be perfectly bare in parts. Steel, copper, or zinc plates may be employed for this work; the two former are more especially suitable for engraving. The mordant usually employed for these may be a mixture of hydrochloric acid with potassium chlorate, which causes an evolution of chlorine. For zinc, hydrochloric acid alone may be employed, though it is well previously to dip the plate in a solution of copper sulphate. For an engraving the biting-in need be but very slight, though much of course must depend on the nature of the work as shown by the thickness of the lines. The thicker the lines the deeper must be the biting-in. For a relief block the biting-in has to be carried to a far greater extent; in fact, as deeply as seen in an ordinary wood-cut. This involves very tedious manipulation after the first biting. The plate has to be warmed, dusted with resin; again heated to slightly melt the bitumen, so as to allow it to flow down the sides of the bitten-in lines. This process has to be repeated till a sufficient depth is attained. When there are larger spaces of white in the print, the metal is usually removed by a fine saw, or a graver. Relief-block making is essentially difficult in almost every stage, and rarely repays an amateur the labour he may bestow upon it.

Ehrard, of Paris, has another method of producing engravings, which is also dependent on biting in. He prepares a transfer, as for zincography, and, after going through the usual manipulations to transfer it to a copper-plate, he plunges it into an electro-plating bath for a few minutes, thus covering the copper with a thin film of silver, the lines of the engraving being protected by the greasy ink. After a rinse in dilute acid the plate is transferred to a bath of mercuric chloride, where the silver is converted into the double chloride. After washing, the ink is removed, and the biting process allowed

to proceed. The details of this process are a secret, but what is stated above gives a general idea of the process. The analogy that exists between this and Fox Talbot's process of engraving a daguerreotype plate is obvious.

Another process for obtaining the same results, various modifications of which have from time to time been announced, is due to Talbot. It consists of printing the negative on a gelatine film, washing away the unaltered gelatine, and making an electrotype from it. In the trade there are several firms who practise either photo-engraving or relief-block making, but it is not known which methods they adopt, as the several processes are kept secret. Amongst these may be named Goupil, Gillot, and Dujardin, of Paris; Dallas, and Leitch & Co., of London. Scamoni, of St. Petersburg, also makes very beautiful reproductions of engravings, &c. His method seems to be based on the building up of a relief on the negative itself, and then taking an electrotype. Fig. 37 is a print from a photo-relief plate by Warnerke, produced by a process of which the details are not as yet published.

As already stated, all these processes seem adapted to the reproduction of line work in contradistinction to half-tone drawings or photographs from nature. Woodbury, however, introduced a method of making plates to give mezzo-tint prints from ordinary negatives, which has been adopted by Roussillon, the manager of Goupil & Co.'s works at Asnières. It is founded on the Woodburytype process, a grain being given by the action of light, the dimensions of the granules depending on the extent to which the light has acted. The student must picture to himself the formation of a Woodburytype mould made as already described having the grain, and he will then readily see that the desired depressions are present for copper-plate printing. It appears that the graver has to be employed to touch up these plates, and it is difficult to know how much is due to the merely mechanical reproduction, and how much to the artist employed upon them.

Fig. 37.

Mr. Dallas, of Gray's Inn Road, has produced photo-relief blocks for the reproduction of half-tone prints, but the details of his process are kept secret. Some of the specimen prints produced by this gentleman leave but little to be desired, especially if they have undergone no retouching with the graver.

We cannot quit this subject without remarking that some very beautiful half-tone typographical blocks were produced by Pretsch as early as 1858, his process being based on that of Talbot, already mentioned.

CHAPTER XXVIII.

PHOTO-COLLOTYPE PROCESSES.

By a photo-collotype process is meant a 'surface printing' process, by which prints are obtained from the surface of a film of gelatine, or other kindred substance. The general methods by which such surfaces are formed are based upon the one fact already pointed out at p. 161, that gelatine, like other similar bodies, when impregnated with potassium dichromate, becomes incapable of absorbing moisture after full exposure to light; and that where light has partially acted, there it becomes only partially absorbent, when compared with the amount it will absorb when entirely guarded from light. Suppose we prepare a film of gelatine with which has been mixed some potassium dichromate, by floating a warm solution of the mixture over a smooth surface, such as a thick glass plate, and when dry expose it beneath a negative in which we have different degrees of light and shadow, as in a landscape or a portrait negative; on immersing the film in cold water, we shall have a picture impressed in which the different degrees of shadow are represented by different degrees of relief. If the back of a similarly treated gelatine film be

exposed to light previously to its immersion, the relief afterwards will be found to be much slighter. This is evidently a necessary consequence. If over either of these surfaces, when all superfluous moisture has been removed, a smooth soft roller carrying a fine layer of greasy ink be passed, it will be found that the greasy ink will adhere to the parts exposed to light in nearly exact proportion to the intensity of light which has acted on them.

With the film in which the relief is high the ink will take less readily, because the roller, even when tolerably soft, will fail to come in contact with the exposed parts. With the film having but small relief the difficulty will not be found. If such a film as the latter be now placed in a printing press, an impression from it may be obtained, but it will be found that as regards right and left the pictures will be reversed. A reversed negative is therefore necessary. Theoretically the number of impressions which can be pulled from the surface is not limited, if the surface be kept damp, and if a fresh application of ink be given by the roller. It will be found, however, that after each pull there is a tendency of the unexposed gelatine to adhere to the paper, and thus to spoil the printing surface. In order to prevent this it has become customary to introduce into the gelatine some substance which will harden it. Certain gum resins, alum, chrome alum, and kindred substances effect this hardening, and one or other of them is to be found in the formulæ given for most of these processes. Albert, of Munich, may be said to have first discovered a thoroughly workable process, based on the above principles, and we shall briefly give an outline of the method he adopted as being a typical one, and unencumbered with any of the large number of modifications introduced at various times by other experimenters.

A piece of plate glass some 2 centimetres in thickness is coated with a gelatine mixture made as follows:—

I.

Good glue	10 grammes.
Water	80 cc.

II.

Potassium dichromate . . .	3 grammes.
Water	40 cc.

These are dissolved separately and mixed warm. The plate is then coated and dried by heat, 5 or 6 hours exposure to a temperature of about 60° C. being sufficient to effect desiccation. The plates are now exposed back uppermost to light for about a quarter of an hour, the gelatine films resting on a smooth black surface, after which they receive over the first a second coating made as follows:—

I.

Gelatine	8 grammes.
Water	100 cc.

II.

Potassium dichromate . . .	3 grammes.
Water	40 cc.

To No. 1 is added 60 cc. of white of egg, and after heating to 60° C., No. 2 is mixed with it, and the solution is filtered through cotton-wool. This coating is dried, and the plate is ready for printing. The exposure depends upon the quality of the light; it must be continued till the whole of the details are visible on the gelatine, and much of the success depends upon the depth to which it is carried. When judged sufficiently printed, the back of the plate is again exposed to light to such a degree that the resulting relief when the film is wetted will be small. The film is now washed to remove all excess of the dichromate, and is again allowed to dry. The dried plate is next placed for 5 minutes face uppermost in a dish containing a 25 per cent. solution of glycerine in water. The back is then embedded on the bed

of a lithographic press by means of plaster of Paris, and is lightly rubbed over with linseed oil, and again slightly damped with water. A soft roller, charged with greasy ink, is then passed over the surface, when it is found that a perfect print appears on the surface. The plate, the surface of which is in contact with a piece of paper, is now passed beneath the press, and an impression pulled. Such a press as that in fig. 36 may be employed.

Mr. Ernest Edwards introduced an important modification of the above by mixing chrome alum with the gelatine to harden the gelatine film. He only uses one coating to the glass plate, and when dried strips it from the glass surface, and prints it in this condition. He retransfers the film to a pewter or other metal plate, and pulls impressions from it when thus supported. By this device the danger of destroying the printing surface, owing to the possible breakage of the glass plate, is overcome, and in consequence the cost of production is diminished. For a full description of the process, which is named 'Heliotype' by the inventor, the student is referred to another work.[1]

The most recent modification of these collotype processes is by Capt. Waterhouse, Assistant Surveyor General of India, to whom many improvements in facilitating the production of mechanical prints are due. We give the process as he describes it in the 'Year Book of Photography, 1877:—

'As a support for the sensitive film I use flat plates of copper, the same as used for engraving, finely grained on one side.

'Having been levelled on the drying apparatus, the plates are washed with warm water, and coated on the grained side, while wet, with a mixture composed of—

Gelatine (Nelson's opaque) . . .	15 grammes.
Water	100 cc.
Potassium dichromate, in powder . .	4 grammes.
Formic acid (when the former are dissolved)	4 cc.

[1] *Instruction in Photography*, Piper and Carter.

'This is applied like collodion, the excess being poured away, so as to leave just sufficient on the plates to give a thin, even coating. About 6 grammes of gelatine in solution is sufficient to coat 1,000 square centimetres.

'When coated, the plates are replaced in the drying apparatus, covered over, and left to dry. If the coating has been well applied, and the plates are fairly flat, the films dry up in the course of an hour or two[1] with a fine, even, glossy surface, perfectly free from the streaks and waviness so common when working with thick films.

'As the formic acid does not exercise a strong reducing action on the bichromate, it is well not to use the plates quite fresh, but to let them harden for a day or two; otherwise the film will be tender, and adhere to the paper in printing. This might, however, be remedied, if desired, by the cautious addition of some hardening agent, such as chrome alum, glycerine, glucose, honey, &c.

'The films are very sensitive, and do not require long exposure. From 10 to 20 minutes in the shade is sufficient for negatives of ordinary density.

'After exposure the plates are plunged into a trough of water, and washed to remove the dichromate, and are then ready for the press.

'Glue rollers are the best for inking, and though I have not had an opportunity of thoroughly testing the endurance of the plates, the wear appears to be very little; while there is no tendency at all for the film to chip or break away from the plate. Owing to the relief being very slight, as well as to the composition of the films, the plates take the ink very readily.

'Any kind of suitable printing press may be used; but vertical pressure is, perhaps, the best, as being least wearing to the printing surface, and preserving the flatness of the copper.

[1] This refers to an Indian climate; the plates in our colder climate should be kept in a room at a temperature of about 50 c.

'The disadvantage of the process is the difficulty of retaining the flatness of the copper plates, and, consequently, of securing their perfect contact with the negative in the pressure frame. With thin plates this may be overcome by strong pressure; but it is better, when practicable, to transfer the negative film to the gelatine surface in a bath of alcohol.'

It is scarcely possible to enumerate all the different collotype processes: we may mention the autotype mechanical process, Pumphrey's and Thiel's, as amongst the most successful.

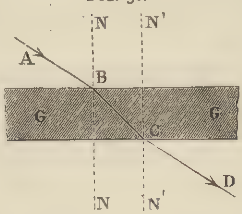
CHAPTER XXIX.

THE LENS.

WITHOUT entering into any discussion as to the theory of light, it will suffice to glance at the more general laws of geometrical optics, such being sufficient to show the principles on which photographic lenses have been designed.

A ray of light, whilst passing through a medium of uniform density, travels in straight lines, and when a ray of light passes from any medium to one more dense, at any angle less than a right angle to the tangent of the common surface, the direction of the ray of light is bent in towards the normal of the common surface; and if the ray pass from a medium to one less dense, it is bent away from the normal. Fig. 38 explains what is meant by the above. Let G G represent the section of a thick sheet of glass with parallel surfaces. Let a ray of light, A B, strike the top surface of the glass at B. Glass being a denser medium than air, the ray will be bent in towards the normal, N N, of the surface,

FIG. 38.

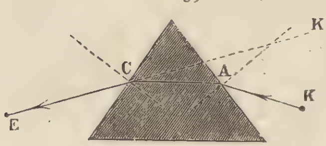


and strike the lower surface of the glass at C; on the ray of light emerging from C to the air it will be again bent away from the normal N′ N′, and move in the direction C D, which is parallel to A B, since the surfaces of the glass plate are supposed to be parallel.

It is found experimentally that the sines of the angles which the ray makes with the normal at the surface of the two media have a fixed ratio to one another, and that this coefficient is dependent on the media through which the ray passes. Thus from air to ordinary flint-glass the coefficient is about 1·5, and from the flint-glass to air the reciprocal about $\frac{1}{1\cdot5}$ or ·66. Applying plane trigonometry to this experimental fact, it will be found that there is a limit to the angle at which a ray of light can pass from any medium to one less dense, since the limit of the sine of an angle is unity. When the ray strikes the surface at this particular angle or at a greater the rays are reflected back, and the limiting angle itself is called the critical angle, or angle of total reflection, for these two media. A reference to this has been made at p. 88.

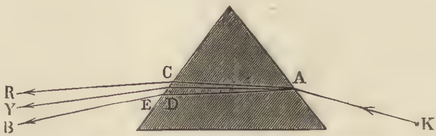
Instead of the surfaces of the glass being parallel we may have them inclined at an angle to one another, and in this case the refraction at each surface will follow the same law. An object which is really at K, fig. 39, will apparently occupy the position K′, which is equivalent to saying that a ray of (monochromatic) light projected in the direction K A would have a direction C E after passing through the prism. If the projected beam of light in the direction K A be white, it will be found, as already noted in the second chapter, that on emerging from C it is split up into rays of the different rainbow tints. If we take any three distinctive rays in the red, yellow, and blue, we shall find that the red is least refracted and falls in a direction R, fig. 40, the

FIG 39.



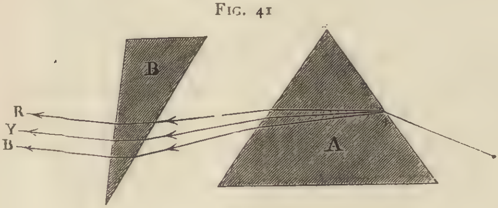
blue most and falls at B, and that the yellow occupies the intermediate position. This difference in the index or coefficient of the refractive power of the media for different coloured rays gives the phenomenon known as dispersion.

FIG. 40.



It is found by experiment that the angles formed by the directions of the different rays of light vary according to the composition of the glass employed for the prism; that with one specimen, for instance, the angle R and Y does not bear the same ratio to the angle formed by Y and B that it does when another specimen is employed. It is owing to this difference in dispersive power of various glasses, that it has been found possible to cause the component rays of white light to be

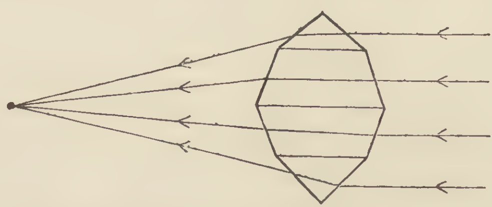
FIG. 41



nearly equally refracted, and yet to show no appreciable colour, due to dispersion. It will be seen in fig. 41 that, by employing opposing prisms of different composition, the dispersion may be almost entirely overcome. Thus it may happen that by placing a prism B of the dimensions, and in the position shown, the rays originally forming white light, and which were decomposed by the prism

A, might be so bent, owing to the difference in the dispersive power of two media, that they emerge from B parallel to each other, instead of each ray forming a definite angle with its neighbour, and that still the original ray may be refracted. Supposing B and A to be of the same homogeneous medium, it is evident that the same result would not be obtained. If the distance between B and A were diminished till the adjacent surfaces touched, the parallelism of the rays emerging from B would still be obtained, and, owing to the small dispersion of the rays in A, an incident ray of white light would emerge as white light. The two media we have been supposing to be employed are only hypothetical. Unfortunately up to the present date no

FIG. 42



two media have been found whose dispersive power can be utilized so as absolutely to correct one another.

Supposing we have a series of prisms and their frusta joined together as shown, it is evident that the surfaces may be worked at such angles that the rays of light proceeding from an object at any distance from them may cut in one point and form an image of that object. In the figure 42 we have supposed the luminous object to be infinitely distant and to form one single image. By rounding off the angles the same result may still be obtained and will form a lens. The curve that a glass would take, to give such theoretically perfect results, would be practically unsuitable, owing to the difficulty of grinding it; and also because it would only be correct for a particular distance and direction of object.

In practice lenses are worked to spherical surfaces, as being most convenient, and being capable of approximate accuracy.

We will first glance at the inaccuracy that the spherical surface may cause when uncorrected by other means. If the rays of light, striking the lens obliquely, or along its axis, be reflected from any distant object, they will be practically parallel rays, and if different annuli of the lens be covered up, it will be found that the point of intersection of the rays will vary, the intersection of the marginal rays will be nearer to the lens than that of the central rays, fig. 43; thus when the whole of the lens is utilised the object will appear wanting in definition owing to what is called 'spherical aberration.' This defect is overcome in a great measure by placing a diaphragm in front of the lens, fig. 44, the oblique rays and the central rays, passing through which, can be brought approximately in focus on a plane at right angles to the axis of the lens.

FIG. 43.

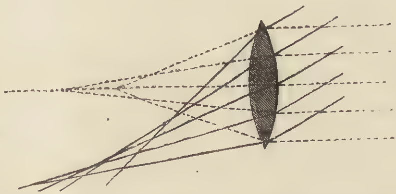
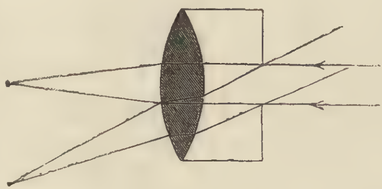


FIG. 44.



Again, a diaphragm has a further advantage in that it allows the focus of a distant and a near object to lie on one plane. The nearer an object from which the rays proceed is to the lens, the longer will be the focus after they pass through the lens. Let the rays issue from a distant and a near object. From fig. 45 it is apparent that if the whole lens be used (supposing spherical aberration eliminated) there would be no plane, X X, on which the two objects would

appear at all defined. The effect of a diaphragm, or 'stop,' as it is technically called, is to narrow both pencils of light so that neither of them is much out of focus at any point intermediate between the foci of the extreme rays. See fig. 46. This will be entered into further on in this chapter.

Supposing that the rays from the near object formed an

Fig. 45.

angle with the axis of the lens, and those from the distant object coincided with it, a larger diaphragm might be employed if the plane on which the images of the objects have to be received makes an angle with the axis of the lens,

Fig 46

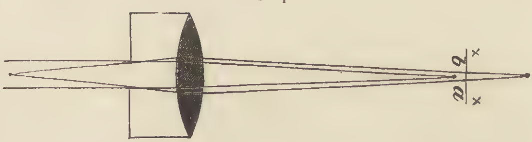


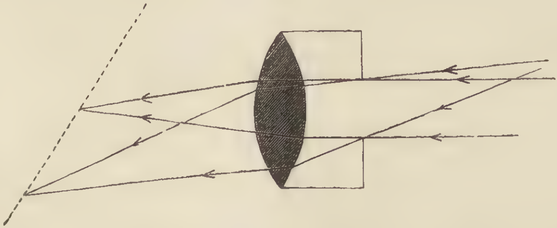
fig. 47. It will be seen that the swing-back of a camera serves this purpose.

It is to be observed that nearly the same results can be obtained by placing the diaphragm behind the lens instead of in front, fig. 48; and also that the size of the diaphragm determines the brightness of the image, for only a portion of the lens is utilised.

With a lens such as shown there is a difference in the resulting images when the diaphragm is placed in front or behind the lens. In both cases we have distortion, but the distortion in the one case is the reverse of that in the other. When the diaphragm is in front of the lens the image of a square would be barrel-shaped. When it is behind the

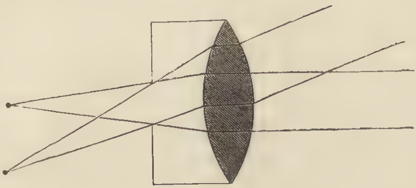
curvature would be reversed, fig. 49. It would be useless in either case to take an architectural subject with such a lens

FIG. 47.



unless the building occupied but a small proportion of the picture. The reason of this distortion will be apparent when it is remembered that the margin of the lens, its surfaces being portions of spheres, will cause greater refraction

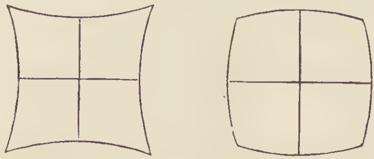
FIG. 48.



than the central portion. When the diaphragm is in front of the lens it is the margin of the lens which gives the image of the corner of the square. The image of the centre of each side is formed by a portion of the lens which is more central, and therefore is less proportionally bent. When the diaphragm is behind the lens different portions of the lens are used to form the image, and consequently the distortion is reversed. By placing a lens on each side of the diaphragm it is evident that distortion due to this cause may be entirely overcome, and thus we get what is called a doublet lens. It will be found that with certain lenses, if we

attempt to obtain a sharp focus of horizontal and vertical lines near the margin of the focussing screen, we shall fail; either the one or the other will be indistinct. This is

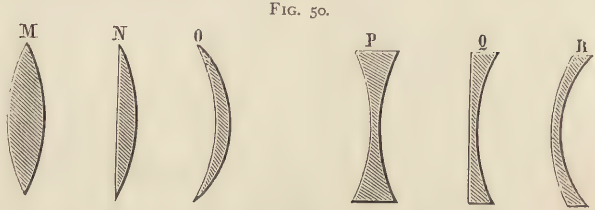
Fig. 49.



due to *astigmatism*, a defect also caused by the spherical form given to the surfaces of lenses.

Lenses have various shapes given to them; the following are the different forms:—

Fig. 50.



M is the double convex; N, a plano-convex; O, a concavo-convex; P, a double concave; Q, a plano-concave; R, a meniscus. Lenses in which the concavity is greater than the convexity can have no actual but only a virtual focus, as may be seen by making a diagram. All such, when combined with other lenses, in which the convexity preponderates,[1] will either increase the focal length or give a virtual focus to the combination. In photographic lenses the chief use of concave lenses is, by making them of suitable glass, to secur achromatism.

The principal focus of a lens is the point where rays which enter parallel meet on emergence. As an example we may refer to fig. 42.

[1] The material in which the lenses are worked must be taken into consideration in determining this.

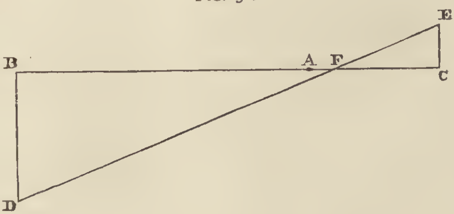
The optical centre of a lens is that point in the axis of the lens through which lines joining any points in an object and their images would intersect.

Any point in any object, and the image of that point are said to be the conjugate foci of the lens; and the conjugate focal distances are said to be the distances of the optical centre of the lens from these two points.

The equivalent focus of a lens is a term applied to a compound lens. It is the focus of parallel rays entering the lens. It is termed equivalent from being compared with a single lens that would produce the same sized image at the same distance from the object.

To find the optical centre of a combination of lenses measure a distance of say 50 metres away from some fixed point, and place a rod at the extremity. From this rod measure a line of say 10 metres in length, exactly at right angles to the first line, and place a rod over this point. Now

FIG. 51.



place the front of the camera exactly over the starting-point of the first line and level it, the lens being in the direction of the first line. Having marked a central vertical line in the ground-glass with a pencil, focus the first rod accurately, so that it falls on the pencil line in the ground-glass. Take a picture of the two rods in the ordinary manner, and measure back as accurately as practicable the distance of the centre of the ground-glass from the starting-point, and also on the negative the distance apart, at their base, of the images of the two rods.

Suppose the first measured line—
AB to be 50 metres; BD, the 2nd line (the distance apart of the rods), to be 10 metres; AC to be 30 centimetres; and EC, the distance apart of the images of the bases of the two rods, to be 6 centimetres.

Then BD + CE : CB :: CE : CF, which is the equivalent focal distance.

$$\therefore \text{CF} = \frac{(50 + \cdot 3)\ \cdot 06}{10 \cdot 06} = 30 \text{ centimetres.}$$

It is, therefore, this distance along its axis from the ground-glass of the camera to the optical centre of the lens.

The student will readily devise the means of setting off the distance thus found on the brasswork.

The relation of the conjugate foci to one another is expressed by the following formula:—

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u}.$$

Where v is the distance of the optical centre of the lens from the ground-glass, u is the distance of the optical centre of the lens from the object to be photographed, f is the equivalent focal distance. From this it will be seen that if u is very great, then $\frac{1}{u}$ is so small that it may be neglected, and there remains $v = f$. That is, the image of an object at a great distance will be at the equivalent focal distance.

Applying the above formula, suppose we have a lens where $f = 30$ centimetres and $u = 40$ centimetres :—

$$\frac{1}{v} = \frac{1}{30} - \frac{1}{40} = \frac{1}{120}.$$

That is $v = 120$ centimetres, or the distance of the ground-glass from the centre of the lens must be 120 centimetres to bring it into focus.

Let it be required that u should be n times greater than

v, which is the same as saying that the image must be $\frac{1}{n}$, the size of the object.

Then—

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{nv} = \frac{n+1}{nv};$$

or—

$$v = \frac{f(n+1)}{n}.$$

Suppose, as before, $f = 30$ centimetres, and it is required to diminish the image of an object to $\frac{1}{4}$ of the size of the original:—

$$v = \frac{30\,(4+1)}{4} = 37.5 \text{ centimetres},$$
$$u = nv = 4 \times 37.5 = 150 \text{ centimetres},$$

or the ground-glass must be 37·5 centimetres and the object 150 centimetres from the lens.

By similar reasoning, if the object is to be enlarged 4 times, it will be found that the above distances must be reversed.

In choosing a photographic lens the purpose for which it is required must be kept in view, for it will be evident that the requirements necessary may be different. In a lens for taking portraits we have, for instance, certain properties which are not essential, and even might be detrimental in a lens for taking landscapes. With the former the objects to be photographed are generally within a few feet of it, and there are a variety of points situated in different planes which ought to be impressed with sharpness on the photographic plate, and that without any distortion. The last desideratum puts the employment of a single lens out of the question, and it is evident that a double lens must be used. Starting with this it is quite evident that the curves of the surfaces of portrait lenses must vary from those for landscape work, and must be so designed as to be capable of delineating points in different

planes not far from the lens itself. It will be found that this can be secured by combining lenses of the same or different focal lengths, separating the pairs by a long interval. This limits the extent of field and necessitates the employment of object glasses of wide diameter in order to cover a sufficient area. In practice the lenses are so far separated that the amount of surface of the photographic plate which can be utilised for some purposes, scarcely exceeds the diameter of the lens itself. Again, rapidity is an essential quality of a good portrait lens, and the curves of the surfaces of the lenses, and their separation, must be so adapted that, without the use of any diaphragm, they shall give a fairly sharp image of a figure or part of a figure when placed at a reasonable distance. Spherical aberration is a positive advantage for some of these requisites. Fig. 52 gives an idea of the curves and also the amount of separation which is given to the lenses of a Petzval portrait combination, on the pattern of which many of the modern ones are still constructed. The dark shaded portions show the crown glass, and the light shaded portions the flint glass lenses.

Fig. 52.

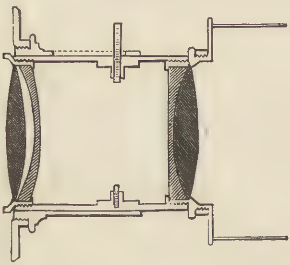
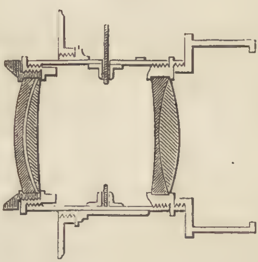


Fig. 53.



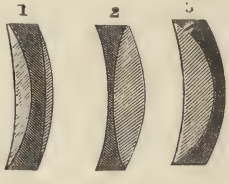
In one of the beautiful portrait lenses introduced by Dallmeyer we have a decided variation from this model. The advantage of this lens, fig. 53, is that two components of the back combination are capable

of being slightly separated, giving a greater depth (though a more diffused) focus than ordinarily obtainable.

For landscape lenses it is not so necessary that points lying on different planes near the lens should be brought in focus on to the photographic plate, but that objects at a distance from the camera, though lying in far different planes, should be sharply defined, and also that objects lying at a considerable angle from the axis of the lens should be in good focus. This latter requisite does not exist to nearly so large an extent in a portrait combination; hence, evidently, the curvatures of the lenses must be different, as also the amount of separation between the two lenses, when a double combination is employed. For ordinary landscape work there is nothing to prevent the adoption of a single lens, since the distortion produced by it would pass unnoticed, though, as already pointed out, architectural subjects demand freedom from all distortion, and, therefore, a combination of lenses has to be resorted to. All single lenses, for certain optical reasons, have the meniscus form given to them, and fig. 54 gives an idea of the forms adopted by some of the best makers.

As already pointed out, the lenses are rendered achromatic, the achromatism being adapted for the actinic rays more than for the visual rays. Fig. No. 1 shows a meniscus flint lens cemented to two crown concavo-convex lenses. No. 2 has a crown double convex cemented to a double concave flint lens, whilst No. 3 shows a crown concave convex lens cemented to a meniscus flint lens.

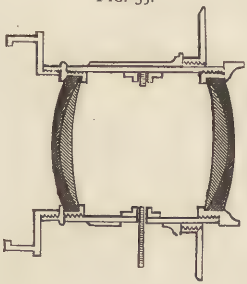
Fig. 54.



Of a combination of lenses for architectural work we show three examples. The first is of the 'rapid rectilinear' type, as made by Dallmeyer, fig. 55. It is formed by a symmetrical pair of lenses of flint and crown; the concave surfaces of the lenses face each other. If we call

the focal lengths of the combination 10·5 in., the focal lengths of each lens will be found to be about 20, and the separation between the two lenses to be about 2 inches.

FIG. 55.



It may be useful to give a rule for ascertaining the focal length of any pair of lenses when combined.

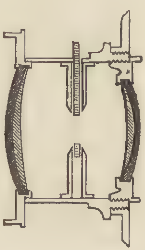
Multiply the focal length of one lens by that of the other, and divide by the sum of their focal lengths less the distance of separation. In the above case we have—

$$f = \frac{20 \times 20}{40 - 2} = \frac{400}{38} = 10·526.$$

The diaphragms for this combination occupy a position half-way between the symmetrical lenses, and, therefore, give no distortion. This lens covers an angle of about 60°.

The next lens, fig. 56, is what is known as a 'wide angle' doublet, in which the separation between the lenses is very small, and their foci considerably shorter, in proportion to the area of the circle that it is to cover. Some of these combinations are made so as to cover a circle whose diameter subtends an angle of 90° from the optical centre. The objection to these lenses is the unequal illumination and the small stop that is obliged to be employed with them, and their consequent slowness.

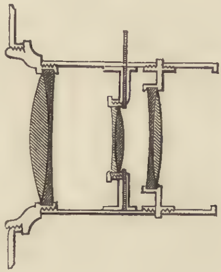
FIG. 56.



The following diagram (fig. 57) shows a section of the 'triplet lens,' in which the place ordinarily occupied by the diaphragm is replaced by a 3rd compound meniscus lens. There were certain advantages connected with this lens at the time when it was introduced, but,

since the manufacture of non-distorting doublets giving a fairly flat field has been perfected, they are comparatively obsolete. It is, however, a good illustration of the ingenuity with which opticians aimed to meet the requirements of photographers.

Fig. 57.



In the doublet lens the position of the diaphragm is important, otherwise—as can well be understood—the second lens will not correct the distortion of the first. In the case of a doublet in which both lenses are symmetrical, the diaphragm should naturally occupy a position half-way between them. If the focal length of the front lens be different from that of the back, the diaphragm must occupy a position proportional to the focal length of the lenses.

With certain classes of doublet lenses as formerly constructed there was formed a fogged central patch on the exposed plate. This was due to what is called a 'flare spot,' which is a circular patch of light seen on the ground glass immediately in a line with the axis of the lens. It is, in reality, an image of the opening in the diaphragm. If glass were perfectly transparent, such a defect could not exist; but, owing to its reflecting light from its surfaces, it has a reality which is often very troublesome. The surface of the lens reflects the aperture in the diaphragm and forms a distinct image of it, and if this image happen to coincide with the focal distance of the lens, the flare spot is sure to make its appearance. By slightly altering the position of the stop this defect is overcome. But as will have been noticed before, the position of the diaphragm in a doublet lens is of importance for eliminating distortion; hence by curing this defect distortion might be introduced. By previously altering the distance of the separation of

the two lenses, both evils may be avoided. At the best it seems, however, that the flare spot is really only distributed over the entire area which the lens covers. This reflection from the surface seems to account in a measure for the veil on negatives, which is often apparent when using certain slow lenses where bright objects have been photographed, and the exposure prolonged to enable the details in dark shadow to be capable of development. The veil is probably the photograph of the illuminated lens.

We must again revert to the diaphragm, or 'stop,' in order to give some further idea of its use, and also of the necessity which may exist for using one of large or small aperture. In the case of a single lens we have already shown that the position of a stop affects the shape of the distortion, depending whether it be placed in front or rear of the lens. It may now be stated—and the reason will be apparent on examining the previous figures —that on the *distance* of the diaphragm from the lens is dependent the *amount of distortion*, as is also the size of the picture which the lens is capable of defining; whilst at the same time the flatness of the field is also in a great measure due to a large distance being maintained between them. In constructing a lens, then, an optician has to hit a mean in order to give a satisfactory result. From these remarks it will be evident that a lens which embraces a wide angle should give least distortion, because the diaphragm must be necessarily closer to the lens than when the angle is curtailed. It is for this reason that the employment of a wide angle lens, with a plate of a size larger than that it was constructed to cover, is found to yield more satisfactory pictures than if a lens capable of embracing a less angle be employed. Thus a wide angle landscape lens intended to be used for a 40 × 30 centimetre plate, gives more accurate pictures on a 20 × 16 centimetre plate than does a lens embracing a more moderate angle when used for the same sized plate.

When a diaphragm is used, with the ordinary landscape lens or a double combination of lenses, there is a certain inequality of illumination of the field. The aperture of the diaphragm is for obvious reasons circular, and when the rays of light strike this in any direction but axially, it is evident that the admitted light must be diminished, varying in fact as the cosine of the angle the rays make with the axis of the lens. Thus the margins of the picture will on this account have less illumination than the centre. Another cause of the falling off of illumination is this:—If we have two equal, and equally bright and equidistant, objects, so placed that the image of one falls on the margin of the plate and of the other at the centre, the area occupied by the first image will be greater than that occupied by the second, and consequently the marginal illumination will be less. Mr. Dallmeyer states in the first of two articles [1] which he has written on this subject, that 'the diminution of light from the centre towards the margins of the pictures from both these causes increases rapidly with any increase of *angle of view* beyond 40°. At this obliquity the extreme margins only receive 80 per cent. of the light falling upon the centre, at 50° it is reduced to 70 per cent., at 60° to 55 per cent., at 70° to 45 per cent., or less than one half. Therefore the larger the angle included in the picture the more apparent becomes the defect.' In the same article Mr. Dallmeyer insists that the aperture of a diaphragm should always be expressed in terms of the focal length. Thus an aperture of 5 centimetres when used with a lens of 50 centimetre focus, should be called $\frac{1}{10}$ aperture, which is a means of expressing the intensity of a lens. The aperture of the diaphragm also determines the amount of depth of focus, and this increases as the diameter of the aperture diminishes. Any point which is out of focus is represented by a disc of confusion, and when such a disc does not exceed a certain diameter, the eye is unable to distinguish it from a point. In practice 1 minute of arc is taken as

[1] *Year Book of Photography*, 1876 and 1877.

the limit. When the diameter of this disc, as viewed from an ordinary distance for examining a picture (40 to 50 centimetres) subtends more than a minute of arc, the object will appear to be out of focus, whilst if less it will be in focus. Hence we may argue that the smaller the aperture of the diaphragm the greater the depth of focus there will be, since the focus of nearer objects and distant ones may all be made to fall within this limiting angle by diminishing it. A reference to fig. 43 will aid the student in comprehending this. Taking a disc of ·25 millimetre diameter, which is about a minute of arc as seen from a distance of 50 centimetres, as the greatest admissible diameter of disc of confusion, a table is readily constructed of the nearest point which will be in focus when any aperture of diaphragm is employed. Suppose we know the equivalent focus of the lens in question to be 25 centimetre focus, and that we are to use an aperture of 2·5 centimetres :

Taking the formula—

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u},$$

when the distance is in focus, the nearest part of the foreground which can be considered sharp will have a focus which is longer than the equivalent focus by ·25 centimetre, for—

$$\begin{array}{ccccccc} \text{Cent.} & & \text{Cent.} & & \text{Millimetre.} & & \\ 2{\cdot}5 & : & 25 & :: & {\cdot}025 & : & x \end{array}$$

$$x = {\cdot}25 \text{ centimetre};$$

$$\therefore \frac{1}{v} = \frac{1}{25} - \frac{1}{25 + {\cdot}25} = \frac{{\cdot}25}{25 \times 25{\cdot}25}$$

$$= \frac{1}{2525}$$

$$\therefore v = 25{\cdot}25 \text{ metres.}$$

That is to say, all parts of the picture lying beyond 25 metres will appear to the eye to be in focus. The following table has been constructed on that basis :—

Intensity, or Aperture Ratio	Relative Exposures	Focal length of lenses in centimetres						
		10	15	20	25	30	40	50
		Distance of nearest distinct objects in metres						
$\frac{1}{10}$	1	4·1	9·1	16·2	25·2	36·3	64·4	100·5
$\frac{1}{15}$	2·25	2·7	6·1	10·8	16·9	24·3	43·1	67·2
$\frac{1}{20}$	4	2·1	4·6	8·2	12·7	18·3	32·4	50·5
$\frac{1}{30}$	9	1·4	3·1	5·5	8·6	12·3	21·7	33·8
$\frac{1}{40}$	16	1·1	2·4	4·2	6·5	9·3	16·4	25·5

The annexed formula will approximately give the nearest point p which will appear in focus when the distance is accurately focussed, supposing the admissible disc of confusion to be ·025 centimetres :—

$$p = \cdot 41 \times f^2 \times a$$

When f = the focal length of the lens in centimetres,
a = the ratio of the aperture to the focal length,

the result is in metres.

In the application of the foregoing formula the student should note the advantage of using a lens of short focus in lieu of one of long focus, viz., that more of the foreground can be placed in the picture without any detriment to it through 'fuzziness.' It can also be shown that an enlargement from a small negative is better than a picture of the same size taken direct as regards sharpness of detail. Suppose, for instance, we wish to compare for sharpness a picture taken with a lens 50 centimetres focus with an enlargement of the same size, from an original negative taken with a lens of only 10 centimetres focus, both having the same aperture ratio, say $\frac{1}{20}$. The negative in the last case would be only $\frac{1}{5}$ the size (linear) of the former. To compare the two the disc of confusion in this latter should only be ·005 centimetres diameter, and this

should give the distance of the nearest distinct object, since, when enlarged 5 times it will give a disc of ·025 centimetres diameter, which we have already taken as the limit of distinctness. Calculating as before for the lens of smaller focal length,

$$\cdot 5 : 10 :: \cdot 005 : x$$
$$x = \cdot 1 \text{ centimetre}$$
$$\frac{1}{v} = \frac{1}{10} - \frac{1}{10 + \cdot 1} = \frac{\cdot 1}{\cdot 1010}$$
$$\therefore v = 10 \cdot 1 \text{ metres,}$$

that is, after enlarging a picture to the size given by a lens of 50 centimetres focal length, an object 10·1 metres will still appear in focus. In looking at the table, it will be found that with the direct picture of the same size the nearest object in focus will be at 50·5 metres distance. Calculation shows that the gain in an enlargement, compared with a direct negative, is inversely proportional to the focal lengths of the lenses. This, of course, refers only to an aplanatic lens, and care must be taken to distinguish between the advantages to be gained in enlargement by the use of a smaller lens, with the disadvantages that ensue from the deterioration in the relative values of light and shade (see p. 257).

The student should remark that in doublet lenses the apertures in the diaphragms do not show accurately the available aperture of the lens. In order to ascertain their correct value, a distant object should be focussed in the camera, in order that the focussing screen may be at the equivalent focus of the lens ; this screen is then removed and replaced by a glass over which is pasted any opaque paper. A candle is brought near the centre of the opaque screen in which a small hole has been punctured. The front combination of the lens is illuminated by the rays of light coming through the orifice, and the diameter of the disc of light seen on the front of the lens gives the available aperture of the lens when used with that diaphragm.

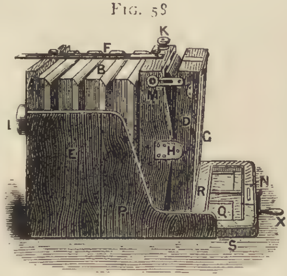
CHAPTER XXX.

APPARATUS.

IT will be unnecessary to describe much of the apparatus that is in daily use by the photographer, as some have already been described in various chapters, and some must be left to individual taste. In those kinds of apparatus which are to be described it must be borne in mind that the recommendations made are merely the results of the writer's individual experience, and it is not improbable that something better may be known to others.

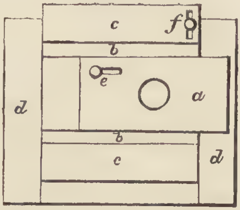
Cameras.—It should be considered an essential in every camera, excepting one used for copying and enlarging, that it should have a back that at least will swing at an angle away from the vertical plane, and it is a great comfort when a movement in a horizontal plane can also be given to it. Technically, the backs which can move thus are termed 'swing-backs.' The accompanying figure will give an idea of a double swing-back, and also of the kind of camera which for landscape work seems everything to be desired. A is the front of the camera into which screws the lens L. The lens can be caused to occupy a position out of the centre of the camera by the double movement shown in fig. 59. *a* is the board to which the lens is attached by means of its flange sliding in the grooves *b b*, which are fixed on to the main movable front *c c*. This front also slides in grooves *d d*, attached to the body of the camera. These fronts are fixed

FIG. 58



a any point required by means of the screws *e* and *f* which run in the slots as shown. Reverting to fig. 58 it will be seen that the camera has what is known as the 'bellows' form, the bellows B being attached to A and also to the swinging framework D. E is connected with R by means of a rod, passing through the side of the framework, and terminated by a clamping screw K. R can be made to approach or recede from A by means of a slow-motion screw turned by the handle X. D is connected with M by pivots which work in the brass plates H, and since C is fixed as regards the vertical plane, it is evident that D can move through any small angle about H, without in any way interfering with the other movements of the camera, and the angle can be maintained by clamping the screw, which works in a slot as shown. Thus, then, a swing away from the vertical plane is secured. The motion of D in a horizontal plane is secured by pivoting the frame M on to R. If the clamping screw K be loosened, M, and therefore D, can be moved through any small angle in a horizontal plane, and can be fixed in that position by tightening K. The double swing motions are therefore secured. F is a bar with a long slot cut in it, so arranged that clamping screws in C and A can fix it and give additional rigidity to the camera. When R has been moved along the tail-board Q, so that C touches A where the clamping screws M and K are loosened, the latter is free to turn up against the ground glass G. When a small pin at S is withdrawn from P, this board, being hinged as shown, folds round the turned-up tail-board and Q, is kept in position by means of a small snap spring fixed to the bottom of the camera.

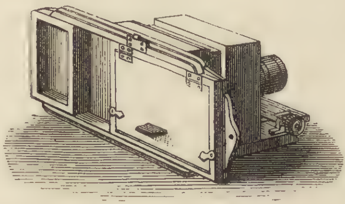
FIG. 59.



The camera itself can be attached to the stand by the tail-board Q, in which position the greatest length of the

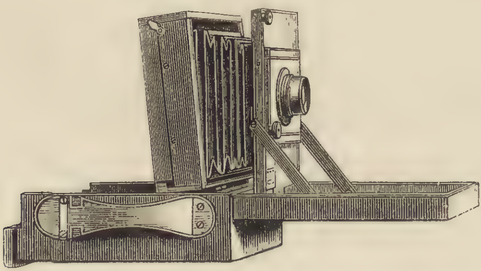
picture is horizontal, or by E when the height of the picture has to be longer than its breadth. A camera 21 × 16 centimetres of this form, when packed in a leather case, weighs about 6 kilogrammes, or 14 lbs. For work in the studio where the diminution of weight is no object, a rigid form of camera can be adopted. Such a form we give in fig. 60. This is a camera adapted for taking cartes de visite, and it will be noticed that the alteration in focus is secured by a different arrangement to that in the last. The front part,

Fig. 60.



which carries the lens, slides outside the back part, the movement being effected by a pair of racks fastened on the base board, on which a long pinion works. Some photographers

Fig. 61.



prefer this motion to that given by the screw, since the hands do not interfere with the position of the body whilst viewing the image on the screen.

It will also be noticed that there is a long carrier for the dark slides, and that the dark slide is more than double the length necessary to secure one picture. The object of this

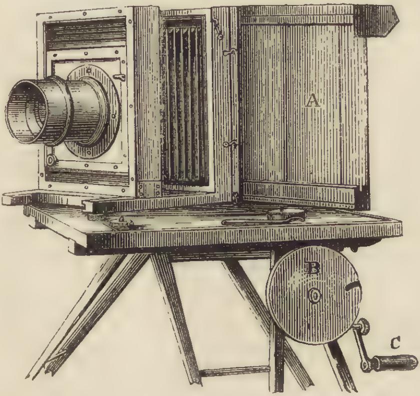
is to be able to give two exposures on the same plate, and thus to economise time.

The latest form of a camera is one devised by Woodbury, in which the bellows form is combined with a very pretty focussing arrangement. The focus of a lens being known approximately, the front of the camera is drawn out to the required length and clamped, and the remaining adjustment given by a slow motion screw. This may be seen in the preceding diagram (fig. 61). The camera is very compact, packing up into a small box.

For some classes of views a panoramic camera is a very useful piece of apparatus to employ. For instance, where the view embraces 120° any lens would be incapable of giving the whole picture, unless at least two views were taken from the same spot and afterwards joined. The fault in such a picture would be that there would be two or more fixed points of sight, which must inevitably give a more or less untruthful complexion to it. In a panoramic camera the eye is supposed to travel round the view, the point of sight altering at each movement of the eye. There is something to be said for this kind of perspective, since the angle the eye sees distinctly at one time is very small in comparison with what is delineated with an ordinary lens. Some of the magnificent views in Switzerland by Braun, of Dornach, were taken by such a species of camera, and they certainly are more pleasing than they would have been had the point of sight been abruptly altered. The accompanying figure (62) gives an idea of Liesang's panoramic camera. In all cameras of this description it is necessary that the rotation should take place about the optical centre of the lens, as by the movement of the lens round that point there will be no displacement of any object near the axis of the lens. The student will remark that a doublet lens giving straight lines is a desideratum, as a single lens distorts, and must of necessity displace objects slightly whilst it is moved round its optical centre. Had it been practicable to have used a curved plate with the radius of curvature of exactly the focal length

of the lens, the lens alone might revolve. As such plates are expensive the following device is employed to enable a flat plate to be used. By means of the cord and pulley, B, shown, the dark slide, A, which carries a long plate, is

Fig. 62.



made to roll on the circle (of which the focal length of the lens is the radius) touching it at that point in which a vertical plane, passing through the axis of the lens, cuts it; and since the only part of the image which can fall on the plate is through a slit, the middle of which lies in the same vertical plane as the axis of the lens, it is manifest that, provided the slit be narrow enough (*i.e.* that the arc does not differ much from the tangent of the angle formed at the optical centre of the lens by the planes passing through the centre and the side of the slit) the picture will not suffer in definition. The exposure is given by turning the winch, C, which causes the rotation of the lens and body of the camera whilst giving the necessary motion to the plate. A band passing round the back of the plate holder and attached to the slit prevents the ingress of light to the sensitive surface, excepting on that portion opposite the slit and passing through the lens.

For the outdoor part of dry-plate work the apparatus is comparatively small, and consists of a camera, focussing-cloth, camera-stand, a set of double-back slides, or a single back adapted to a changing box, or a Warnerke roller slide if the sensitive tissue be employed.

A double back is of very simple construction. The slide is divided into two parts, hinged so as to fold one against the other, one portion carrying a thin blackened and hinged iron or tin plate. A sensitive plate is put in each half of the slide, the sensitised surface being outwards. The blackened plate prevents the passage of light from one to the other. The plates are placed in the camera as usual, and opened for exposure as with the ordinary slide.

It will be seen that for every couple of plates one double back is required, and it will seldom be convenient to carry more than three of these, on account of their weight.

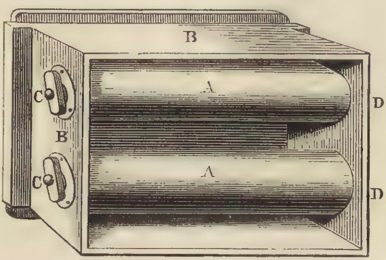
If it be decided to use a changing box, there is none better than that manufactured by Hare. In order to use it, it is necessary to have a dark slide specially constructed, the peculiarity of which consists in its having a movable end-piece through which the plate passes into the holder. The plate box itself has a lid, which is longer than the top of the box, and is capable of folding, and in it is a slot through which a plate can pass in or out of the box. The box itself is fitted with grooves, the positions of which are marked on the outside of the lid by an ivory scale. In order to fill the slide, its end is slipped into a groove which borders the slot, and when it is home a spring is forced on one side, and this opens the end of the dark slide, and the slot in the shutter is uncovered. The

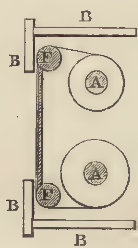
Fig. 63.

lid of the box is now moved till the slot in it is over a plate as registered by the scale. The box is now gently inverted and the plate passes into the dark slide. This latter cannot be removed till the shutter once more covers the slot, and the act of removing it closes the shutter over the opening. This is a very simple method of changing a plate even in bright sunshine, and is always successful provided the plates are carefully cut to the proper size. The method of returning an exposed plate to the box is self-evident. The weight of a dozen plates and this changing box should not be much more than that of half a dozen plates in double backs.

Warnerke's roller slide is of necessity only applicable to sensitive tissue. The diagram gives an idea of its construction:—

FIG. 64.

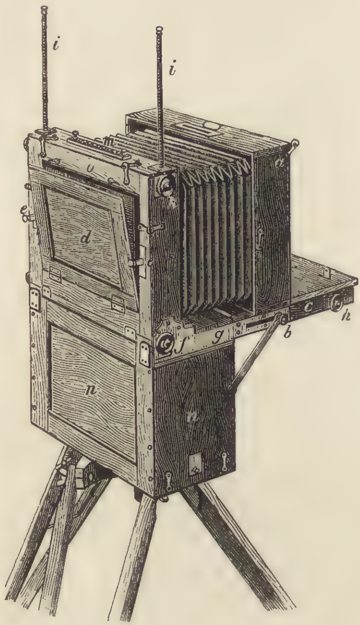




A band of sensitive tissue is rolled round one of the movable rollers A, and after passing over F F, which consists of a couple of round bars and a flat blackened board, is attached to the other roller A. The band can be made to pass from one to the other by turning a thumbscrew placed at D D, and can be fixed at any time by the clamping screws C C. It is thus evident that after an exposure has been given to one part of the tissue, another portion may be brought forward to receive a fresh exposure. The rollers &c. are enclosed in a box B, which answers to the ordinary dark slide, the sensitive surface being protected by an ordinary shutter.

The Jonté dry-plate camera is represented by the following diagram :—

FIG. 65.



After the folded-up camera has been fixed to the stand, *c* can be opened by opening the hook *a*, and unfastening a button. The front of the camera is pushed forward to the approximate focus of the lens, and is clamped by a button. To focus, the door *d* is opened and the ground glass is put in position by means of the buttons *e e*. On *g* is an indicator, and it can be fixed in position, in regard to an attached scale (which corresponds with the number of plates in the box) by the screw heads, *f f*. The focus is obtained by means of the milled-headed screw *h*, the door *d* is shut, and the ground glass is brought back-

wards, by altering the buttons *e e*. A plate can now be raised by means of the screws, *k k*, working in the racks, *i i*. *m* is a perforated plate; a strip of paper is inserted under it, and every plate, whilst being raised, presses on a corresponding iron pin, and perforates a hole in the paper, thus registering every exposed plate. The front of the camera can be tilted when necessary, by means of the screw *b*. The plates are inserted from the bottom part of the box *n*. The advantage of this apparatus is that there is no dark slide, and consequently no possibility of introducing air, light, or dust inside the cameras. Wet plates can be preserved in a moist condition for several hours in this apparatus. It is made of any size.

It may be mentioned that a capital substitute for ground glass may be made by coating an ordinary plate with the following varnish :—

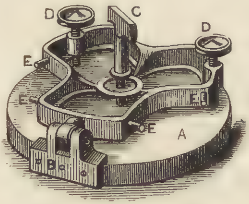
Ether	500 cc.
Mastic	30 grammes
Sandarac	30 grammes

After dissolving these resins, benzine is added little by little till the grain becomes sufficiently pronounced.

In order to ascertain whether the plane of the silver wires of the dark slide is the same as that of the ground surface of the focussing screen, a bright object should be focussed accurately on the latter. The slide should next be filled with a piece of ground glass, the rough surface being placed next the silver wires and placed in the camera. If the image retains the same definition it may be presumed that the focussing screen is correctly placed. If greater accuracy is desired the method of focussing given at p. 269 may be adopted. It is as well to test the purity of the silver wires which are in the dark slide. The usual contamination is copper; if a drop of dilute nitric acid be applied to the wire an absence of green colouration, due to the formation of copper nitrate, may be deemed conclusive that the silver

is tolerably pure. In any case, however, it is a good plan to give the wire a coating of shellac varnish. Another point about the dark slide which should be alluded to is that its front should not be less than $\frac{1}{8}$ inch away from the surface of the sensitive plate. A nearer approach is apt to cause markings.

FIG. 66.



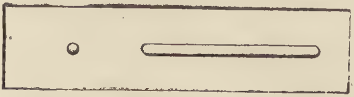
Camera stands.—The camera-stand next requires a few remarks, as the comfort of working depends much on the form adopted. The essentials of a stand for landscape work consist of rigidity, lightness, and compactness when folded up. The annexed diagram gives a form which is convenient, though perhaps rather heavier than is desirable. It is on Kennett's principle, with a modification introduced by Lane. The inverted top is shown in the diagram, fig. 66. A is a circular mahogany disc to which is attached a brass hinge B of the form shown. On this hinge works the whole of the brass framework to which the legs are attached. C is a screw which passes through the centre of the framework, and also through the wooden disc, and it is by this screw that it is attached to the camera. It will be noticed that C has a collar half-way down, and that this can clamp the camera to the disc when required. D D are levelling screws, by which the disc (and consequently the camera) can be accurately levelled. E E are pins into which the tops of the tripod legs fit. Fig. 67 gives an idea of the appearance of the

FIG. 67.

tripod when ready to receive the camera. *c c* are brass collars which are fixed to the top half of the tripod. *d* and *f* are movable collars which respectively clamp the bottom half *b* of the top to the top half *e*, and the top half to the head to which the camera is attached. When not in use the head is detached, the bottom halves of the legs slide into the top halves; and they are strapped one against another and form a comparatively compact bundle.

The subject of the camera-stand cannot be passed over without mentioning the very ingenious method that has been made by M. Warnerke for combining ordinary pictures, taken from the same point, to form a panoramic view. In order to secure an accurate junction of two pictures taken from the same point, but in different directions, it is necessary that the lens and camera should revolve about the optical centre of the lens, for the same reasons as were given when describing the pantascopic camera, p. 214. By adopting the accompanying device, fig. 68, this can be secured. The camera-stand is screwed to the small hole, and the camera itself is attached by a screw to some point in the slot. When the hole is vertically beneath the optical centre of the lens, and the camera is turned, it moves round the optical centre of the lens.

Fig. 68.



Lenses.—As regards the choice of lenses, it is very difficult to give advice. If the student is confined to the choice of one lens for landscape-work, he should unhesitatingly procure a doublet-lens, which has no perceptible flare-spot, and which embraces an angle of about 50°, since with it he can take both landscapes and architectural subjects. If he can afford another lens, perhaps a landscape wide-angle lens is next to be recommended, being exceedingly useful in most positions and giving great brilliancy of picture.

The most complete battery of lenses would be a rectilinear doublet, embracing an ordinary angle ; a wide-angle doublet, to embrace about 90° ; a couple of single landscape lenses, one embracing about 50° and the other about 70°.

For portraiture, the most useful lens is one which will give a 'cabinet' sized picture, and it may be supplemented by one of those quick-acting lenses, which are familiar to all portraitists of the day, for taking instantaneous pictures of children, &c. It should be noted that many fine portraits and groups have been taken with the ordinary landscape doublet-lens, which, though slower than the portrait-lens, yet is sufficiently rapid to be usable.

The dark tent.—There are numerous patterns of dark tents in the market, some very simple and some complicated. Amongst the former may be reckoned Howard's tent, which is, *par excellence*, the very simplest which as yet has been made.

Fig. 69.

The above figure shows the essentials of the tent. The support for the tent is the camera tripod stand. It consists of a triangular pyramidal bag made of India-rubber-lined cloth, which fits inside the legs when they are extended. About half-way up the bag is fitted a mask which is capable of fitting closely to the face, and through it the inside of the tent can be seen. The nose and mouth are not brought

within the cloth, the eyes merely being placed against the peep-holes. Below the mask, in about the position shown, are two sleeve-holes with attached sleeves, terminated with India-rubber bands, causing them to fit tightly round the arms. On the right-hand side of the pyramidal bag is a square hole cut in the black material, in which is fitted orange adiactinic silk or cloth, to admit sufficient light to illuminate the interior of the tent. In the third side is cut an aperture sufficiently large to admit the dark slide and anything that may be required inside the tent. At the bottom of the bag and on the left side is a well in which the portable bath can be placed, sufficient rigidity being given to the bag by a couple of light iron rods. The bag is kept stretched on the legs by means of brass loops, which are fastened to brass eyelets fixed on the camera stand. When the camera stand has been placed in the position whence it is desired to take a view, the tent, which may have been tucked round the stand is made ready, the bath placed in the bag with the dark slide. A plate is collodionised outside the tent (or inside if there be much dust flying about), and immersed in the bath. The bath is then covered, and when the plate is fully sensitised it is placed in the dark slide, the arms being inserted in the sleeves and the head in the mask. The slide charged with the plate is withdrawn through the flap, and after the exposure is made, it is returned to the interior of the tent. The development can be effected in a developing dish which Mr. Howard has constructed. It is slightly larger than the glass plate, and has a couple of bars placed across the bottom in order to prevent the glass being in contact with it. The material may be of gutta percha, as it is light. The bottles containing the developer and intensifier and water are ready within the tent, and the former is applied to the plate when placed in the dish in the ordinary manner after the bath has been covered over. When the development is complete the plate is flooded with water and the intensifying solution applied if necessary. After a slight rinse with water again, the tray con-

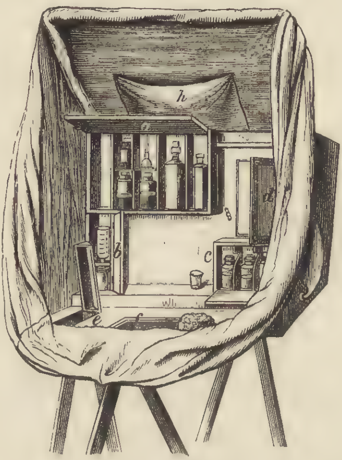
taining the plate, the developing and intensifying solutions, and the water, is withdrawn, and the plate fixed outside the tent.

The operator sits down to develop, his seat being the box which contains his chemicals and bath. It is not necessary to pack away the tent each time the camera is shifted; by removing the iron rods, above alluded to, it folds within the tripod. The chemical chest and camera with the attached tent can well be carried by one person. This tent is suitable for pictures up to 17 × 12 centimetres and is certainly most convenient.

The next tent that will be described is one of Rouch's form which has been slightly modified by the writer. When closed it forms a shallow oblong box. When opened, the lid forms the front of the tent, and the cloth is extended over the breadth of the box by means of movable iron rods.

The developing and other solutions are carried in the small cupboard *a*, beneath which is a space in which can

FIG. 70.



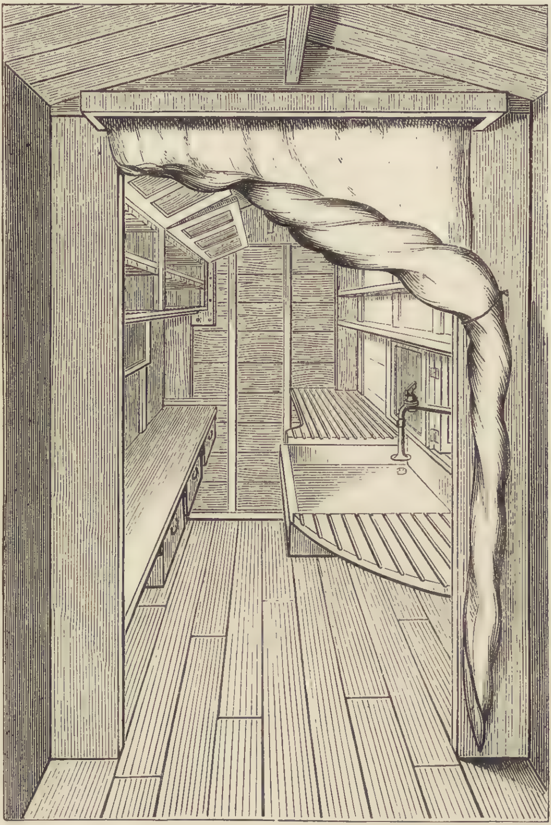
be carried a box divided centrally into two divisions, one half to carry clean plates, and the other to act as a draining

box, similar in principle to that given at page 84. *b* is a small cupboard in which the developing cups, cotton wool, and sponge are kept, whilst *c* contains carefully decanted bottles of collodion. *d* is the window covered with non-actinic cloth, opening inwards, so that when it and the outside door which protects it are opened, white light can be admitted. Across *d* runs a curtain, which can be removed in dull light. On the top of *c* and against the window the travelling bath is placed when the tent is packed: though when in use it is slid into a well on the left-hand side, and protected by a frame covered with waterproof material, *e*, hinged at the far end. The frame fits over a fillet, to prevent any light being admitted. *f* is a waterproof sink, connected with which is an India-rubber tube to carry off the waste water. At the side of the tent is an India-rubber water bag, the tube from which passes through a light-tight connection in the cloth side of the tent. The tube is terminated by a clip.

Over the window is a small shelf, which can fold up against the front, and on it is kept the badger-hair brush for dusting the plate. From underneath the shelf spring two varnished deal battens, which can be turned underneath it, and these are used to support the clean plate when necessary. The plate can be coated inside the tent, and be immersed in the bath with the cloth up in the position shown. The dark slide rests against the space beneath A, and is then ready to receive the sensitised plate as soon as the tent curtain has been folded round the waist of the operator so as to exclude all light. This exclusion of light is easily maintained by the body lightly touching the front of the lower part of the tent. When the developing operations are proceeded with, the plate is removed from the dark slide, and the latter is placed in the pocket *h*, in the top of the tent. The legs of the tent are of the ordinary tripod form, and are fitted on to a square frame which is secured to the bottom of the tent by thumb screws. In order to work in a tent of this description

an assistant is necessary, unless all the apparatus can be placed in a light spring truck. This is seldom feasible. If a well beaten and tolerably smooth road be traversed,

FIG. 71.



an assistant can well carry this tent and legs, whilst the operator can carry the other apparatus, supposing the size of plate to be used not to be larger than 21 and 16 centimètres. The writer worked with this tent in Egypt

for some months and found it very convenient and tolerably cool. This would not have been the case had the cover been made of India-rubber sheeting, as is often recommended. One thickness of black twilled calico, and two of orange tammy, were the materials with which this tent was covered. A white cover might be an improvement.

Although not coming under the head of apparatus, it may be convenient here to show what may be considered a model dark room on a small scale. It is taken from the pattern of one attached to the Transit of Venus expedition, and was designed by De la Rue. The cupboards on the left-hand side were used as drying cupboards for dry plates.

CHAPTER XXXI.

ON THE PICTURE.

In a text book of this class it is impracticable to enter into the discussion of all the rules which should govern the composition of a picture. It will suffice to point out a few of the leading ones which should be followed. In comparison with the painter, the photographer is sometimes under a disadvantage, in that he is unable to choose a point of view to represent some particular feature, in which everything that is objectionable to artistic feeling may be left out or modified, or in which some extraneous object may be introduced in order to give proper harmony to the picture. Thus the painter may render a distant landscape in a favourable aspect of light and shade from some particularly suitable spot, though the foreground which may be at hand may be totally unsuitable for pictorial effect. The latter he may discard for one which may be better fitted for his purpose, taking it from any other locality, providing it is not incongruous. The photographer, on the other hand, is rarely at liberty to use this artifice, unless he resort to

the laborious process of printing from two or more negatives, although when the object is attained the result amply repays any labour that may have been expended. It need scarcely to be said, when combination printing is resorted to, that the greatest care is requisite to avoid incongruity, or an inartistic massing of light and shade. When confined to a single negative, there is nothing for the photographer to do but to make the best of his landscape, including his foreground. This usually entails a sacrifice to a certain extent of either one or the other, and it is the possession of the knowledge as to where the sacrifice is to end that marks the difference between the successful artist and the mere manipulator.

Besides focussing the object by the lens, as will be presently described, there is the focussing of the picture as a whole; that is, the securing of the necessary harmony of light and shade. In a good and artistic photograph the object on which the subject of the picture is to be built should stand prominently out in the print, the eye should instinctively rest upon it without being distracted by other parts. Thus sweeps of shade may lead up to a more highly lighted portion in which should be the principal object, or a sweep of light may lead the eye to a dark object which then should occupy the same prominent position. In a negative as it is developed this may often be unattainable, but by judicious masking of parts during printing this harmony may generally be secured, providing the taste of the operator has been educated. It cannot be expected that an inexperienced photographer can at once form his picture, so as to give the best possible combination to the materials at his hand, until he has attained a thorough practical knowledge of chiaroscuro, and is able to translate the colours he sees on the ground glass of the camera into monochrome.

In choosing a point of view for a photograph, then, it is necessary that there should be this instinctive translation of colour into monochrome a knowledge of the rules which

govern the formation of an artistic picture ; and a perception of the masses into which light and shade should group themselves.

FIG. 72.

Supposing that the photographer intends to make the study of an old wrecked boat lying on the sea shore ; the colour is most deceptive, the general tone being of one tint. In fig. 72 we have the example of such a study taken by Manners Gordon, a gentleman whose productions are always artistic. In analysing the work we find that he has obeyed certain rules. Thus he has made the keel to occupy a position about $\frac{1}{4}$ way up the picture, and the nearest point of the stern occupies about a similar distance of the length of the picture. The landscape being subsidiary to the boat, he has caused the horizon line to be about $\frac{1}{2}$ way up the picture, and in order to break uniformity, he has so arranged that the boat should not be symmetrically placed in regard to the centre of the plate. The lines of boat also make an angle with the horizon, and these are again balanced by the thwarts, &c. It would have been a very easy matter to have made the picture wanting in harmony by placing the camera more to the right, and causing the lines of the boat to run parallel to the

horizon, in which case the boundary of the small pool of water in which it is lying would have had the same direction. The keel of the boat might also have been placed nearer the bottom of the picture, and the general mass of it have occupied a central position. In this case there would have been a symmetrical picture, the general lines running parallel to the horizon and at right angles to it, the result of which would have been that the eye would be partly satiated with it, and there would have been little variety and much monotony. As it is, the picture, which can only be faintly represented by the woodcut, is pleasant to look at.

Instead of a boat being the object to be delineated, we may have it as an accessory to a landscape. As an example we have a view, fig. 73, taken on the Thames by Woodbury. *The*

FIG. 73.

object of interest is undoubtedly the village beyond, with its church, and middle distance formed by the trees. If the boat were taken away there would have been a large space of bare shore, unbroken by any object to relieve its monotony. The boat, however, happened to be there, and the artist has seized the chance to make a picture. Notice how it is made subsidiary to the general landscape. It does not occupy

such a prominent position as in the last example. It is kept about $\frac{1}{6}$ from the edge of the picture, and the keel occupies a little over $\frac{1}{4}$ of the distance from the bottom, and the line of the village is placed about $\frac{1}{3}$ up. Were the boat brought lower down or more central, it would have appeared to have been the 'motive' of the picture. It is evident how such a picture might have been spoilt from a want of

Fig. 74.

knowledge of art rules; as it is, it is a beautiful example of artistic photography.

A third example of a study of boats is given to show certain other points which are often neglected. We have here, fig. 74, a specimen of a picture that might have been readily spoilt. It should be noticed how the lines of the masts, sails, and pier are parallel, and were the figure removed from the side of the boat, and the small skiff made to lean in the other direction, the effect would have been to give the idea that the boats, &c., were tumbling out of the picture, and a sense of instability would have been created. The opposing line of the mast of the small skiff, the inclination of the figure, and the small post in the foreground,

balance the general lines, and no impression of insecurity is left. The general composition, too, of the picture should be noted. The lines forming the extremities of the spars fall on the body of the skiff, while a sense of support to the outer line of the large sail is given by the post. The line forming the top of the post and the top of the pier also approximately passes through the cap of the man and the top of the mast of the skiff. The picture is then built, as it were, on diagonal lines. A slight change in the position of the camera would have altered all this. Again note that the general mass of light is opposed to the black hull of the boat, intensifying the interest with which the boat, evidently the principal object in the picture, is regarded.

Fig. 75.

The accompanying woodcut, fig. 75, taken from a photograph by Woodbury, well illustrates the treatment of an old watermill. In this case the angle of the wall, that is, the base of the corner of the most prominent piece of masonry, is placed about $\frac{1}{4}$ way up the picture. Had it been placed lower it would have been aggressive, whilst if placed higher it would not have given sufficient solidity to the mill. The water-wheel base, the object of interest, is placed nearly centrally in the breadth of the picture, as from the subject there is no danger of symmetry, which

is always distasteful. The shoot of water occupies a position central in both directions. Had it been placed much lower, there would have been a sense of a want of falling room. It will be noticed that the fall of the water naturally enhances the effect of the composition, and the light on it at once attracts the eye from the dark surroundings. If the picture be covered from the bottom to where the board is thrown across the stream, it will be seen how a slight variation in the position of the camera might have altered the general aspect of the picture.

A favourite study with some photographers are forest scenes, and the next two examples shall treat of them. In the

FIG. 76.

first, fig. 76, we have an old oak surrounded by smaller trees, the foreground composed of bracken and ferns. The base of the tree is placed about $\frac{1}{4}$ way up the picture, for if lower there would have been a feeling that there was not sufficient ground for *it*, the principal object, to have taken firm root in, and there would have been a sense of unfitness of position. Had it been placed higher the foreground would have been too prominent, and the first idea might

have been that the *raison d'être* of the picture was simply the ferns in the foreground, for those at the foot of the picture would have been out of proportion to the oak to play the part of an accessory. The distance, or what might be called the horizon line, is drawn about $\frac{1}{2}$ way up the picture, but being so broken by the shrubs and smaller trees it is invested with no importance, and consequently need not be dwelt upon as following any particular rule. The outside of the trunk of the oak is placed $\frac{1}{4}$ way from the right-hand edge; had it occupied a more central position the picture would have appeared cut in two by it. As it is the dark foliage behind it fills in the side of the picture, and there is no feeling that the oak is out of place. Had the foliage been light there would have been a danger that the eye might have been offended, but this is one of the cases in which the position of the camera must be made subservient to the operator. The whole force of the picture is given by the light, which breaks against the trunk of the oak; and as with the trunk, so with the branches, care has been taken to prevent any single bough cutting the picture into two divisions. Notice, too, the stability given by the straight stems of the trees, in the distance.

In the next picture, fig. 77, we have the distance, or perhaps more strictly speaking, the middle distance as the point of interest. The horizon line is kept in the weakest part, the centre, of the picture. The trees in the foreground are so grouped that they frame the view with dark masses, relieved by the light foliage of some of the nearer bushes and shrubs. The foreground finishes at a distance of about $\frac{1}{4}$ from the bottom. More of it would take away from the value of the middle distance, as it would place it in the weakest part of the picture—viz., centrally; less of it would have rendered the picture bald, and have cut off part of the deeper shades which are so valuable in giving the effect of distance to the stream beyond. This picture would have been spoilt had the

camera been so placed as to give more top foliage, since the bough which now partially crosses the picture at about $\frac{2}{3}$ the height, would have caused an ugly division, and also the tops of the distant trees, and the sky would have appeared. This latter, in views such as that under criticism, is objectionable, as patches of white give the eye an inclination to wander off towards it, and it would have been an insufficient precaution to have printed in clouds from another negative,

FIG. 77.

owing to the difficulty that would exist in subduing at the same time the lights on the leaves of the near trees. As it is, the picture is in pictorial focus. By placing the stream to the right or left, the balance would have been wanting, and its general direction would have been altered to such an extent as to have given a feeling that it was a subsidiary part of the picture instead of an essential.

The next example, fig. 78, is intended to show a picture taken on the diagonal; not on an absolutely straight line, but one in which the general direction of the picture is on the diagonal. The point of interest is the extreme distance of the stream, and accordingly it is placed in one of the strongest positions in the picture, viz., $\frac{1}{3}$ way in both directions

from the margins, and it contains the highest light, as seen in the water. This brilliant light is repeated in the clouds, and more faintly still it is echoed in the rocks, where it takes approximately the same form, though it is repeated in a lower tone and of different dimensions. The picture might easily have been spoilt by placing the distance in a

FIG. 78.

— $\frac{1}{3}$

central position, and by arranging that the dark moss-covered rocks in the foreground should have been shifted to the side. Had these dark masses been closely opposed to the highest light, the value of the distance would have been increased, though in their present position they are fairly well placed.

In the succeeding photograph we have a capital example by Manners Gordon of a picture built up on purely artistic principles. The principal object of interest is the cottage, the value of which is enhanced by the admirable grouping of the sheep. The middle distance and background may be considered merely as accessories to support the subject of chief interest. The general direction of the picture is on the diagonal, being carried down from the chimney-top of the cottage along the bank-side to the right-hand bottom corner. The value of the composition lies principally in the

light on the two sheep in the centre group, which reflects itself as it were in the whitewashed cottage front. This may be seen by imagining the front to be of the same local colour as the gable end of the cottage, or by first hiding the sheep by the finger, and then contrasting the effect produced on the mind with that as shown. It may be remarked that

FIG. 79.

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the opposing lines of the clouds balance the lines of the landscape, which would not have been the case had the general contour of the clouds followed in any degree the contour of the sky-line In a woodcut it is impossible to give all the expression that is to be found in the photograph, but the student may gain a fair knowledge of the rules which have been followed.

As regards the introduction of figures into a landscape, it may be necessary to say a few words. It should be clearly understood that the one must be made subsidiary to the other; that is, if the portraits of the figures are required they must be made the principal objects, and the whole landscape must be made subservient to them. On the other hand, if a landscape is to be photographed, the figures, though prominent, yet should occupy such a position as to be subordinate to it, though they may enhance and give the 'forte' points to the picture; and above all things care must be

taken that the figures compose as well with each other as with the landscape.

Robinson, in his 'Pictorial Photography,'[1] a work which every photographer should possess, says: 'The figure must be *of* the subject as well as *in* it, in order that unity may be preserved; it must be used with a purpose to give life to a scene, or to supply an important spot of light or dark; to give balance, or to bring other parts into subordination, by either being blacker or whiter than those parts; and that what is to be avoided is the indiscriminate dragging in of figures into scenes in which they have no business, and where they do nothing but mischief.'

We have such an example in the cut below, taken from a photograph by H. P. Robinson, called 'Blackberry

FIG. 80.

Gathering,' fig. 80. The landscape is one which is most unpromising in its aspect; the sombre bank of blackberry-bushes alone, would form a melancholy, gloomy, picture; but by placing these figures, as they are, some $\frac{1}{4}$ way from the left-hand side, the contrast of light they offer to the deep shadow behind them at once attracts the eye, and leads it gradually up the winding broken path beyond.

[1] *Pictorial Photography.* Piper and Carter.

The spot of light, in fact, affords the exact balance required to what otherwise would be an uninteresting picture. It accentuates everything, as it were, and gives the 'forte' point, which is such a desideratum.

Again, in this study we have an example of the value that a sky gives to a picture. It should be noticed how the lines of the clouds balance the lines of the hill. If the left-hand dark cloud be covered up how wanting in vigour is the composition. It will be seen how Robinson, out of such unpromising materials as a blackberry bank, a couple of figures, and a good cloud negative, has been able to build up a *picture* which is technically perfect and full of interest and repose.

In the next illustration, fig. 81, which is from a photograph by the same artist, we have a capital example of the correct grouping of figures to form a picture in which they are the

FIG. 81.

objects of interest, and the landscape merely subsidiary, though essential. Like the typical picture by Sir David Wilkie's, 'The Blind Fiddler,' this, which is named 'Holiday in the Woods,' is built up on a series of pyramids, the base being curved. It should be noticed how one pyramid runs into another, each corner being differently supported; as, for example, the right-hand corner of the big pyramid is

supported by the basket, and the left-hand corner by the arm of the reclining lad. Tracing the composition all through, it will be seen the lines have been artistically kept in view and the figures posed accordingly. The straight lines of the distant trees contrast with the fall of the pyramidal lines, and give a firmness which would otherwise be wanting. The nearest object, too, is made the most distinct, whilst the darkest object, which is the figure of the boy, cuts across the highest light, giving just sufficient contrast and no more. Had the lad's head been raised higher the effect would have been to form two patches of white, from either of which the eye would have wandered by the attraction of the other. Again, leaving the main group, the two small figures lead the eye instinctively to the distant glade beyond, so that over every part of the picture we are led to some fresh beauty.

Very different are the groups so often seen as posed by many photographers. Either the heads of the standing figures are placed nearly in a line or, if a pyramidal composition is attempted, there is only one pyramid to satisfy a rule which was never intended to be rigid. In grouping there should be no uniformity; if possible, every set of figures should form a complete study by itself, blending themselves into the other sets, whilst the whole should be in harmonious lines. Again, the effect of deep shade in some figures should be made to contrast with the lighter parts of others, care being taken that no patches of light or deep shadow should be obtrusive. Above all things, in posing a group, let it be remembered that each figure is animate, and should not be made to look as lifeless as a statue. Let every member of it have a definite purpose in the group, the apparent occupation of each being in keeping with that of the others.

The next cut, fig. 82, is left for the student to find out the rules that have been followed in the composition, and also to note any improvement which might have been made in it.

We may now sum up a few of the principal rules that should be observed in the composition of a picture, though it must never be forgotten that a rigid adherence to them at all times is impossible. The great point with the photographer is to know when and how he may transgress without spoiling the treatment of his subject.

1. If the object of interest be on the foreground, its base should occupy a position of from $\frac{1}{4}$ to $\frac{1}{3}$ the height of

Fig. 82.

the picture; if it be in the distance its base should be about $\frac{1}{3}$ way up the picture.

2. In a general landscape the horizon lines should occupy a position about $\frac{1}{3}$ way from the top or the bottom of the picture; with the latter a cloud negative will probably be required.

3. It is advisable that the general line of a picture should run on a diagonal or take a pyramidal shape.

4. A long obtrusive line should never be permitted to intersect the picture; it should always be broken up as far as possible.

5. A picture should never be cut in two by a dark object against a light background or by a light object against a dark background.

6. If the general features of a picture have a wedge-like form, care should be taken that the wedge is supported near the point, in order to give the idea of stability.

7. The general lines of a picture should be balanced by opposing lines, for the same reason as that given in 6.

8. A large patch of one approximately uniform tint is distasteful to the eye, and should be broken up, if possible.

9. The object of interest should be pictorially focussed by a general sweep of light (if it be a dark object) or of shadow (if it be a light object), thus causing the eye to fall naturally upon it.

10. Avoid monotony, whether in *constant* repetition of lines, lights, or shades, and never allow a picture to be symmetrical on the right and left of its centre. A repetition of a high light once or twice in a *lower tone* is, however, much to be recommended. See figs. 78 and 79.

As regards 8 and 9, it must be borne in mind that in the printing of the picture a great power is placed in the photographer's hands; by a judicious masking of parts he can cause pictures which would be inartistic to become merely inoffensive, and he may give an atmospheric effect otherwise unattainable by remembering that shadows in the distance tend to become lighter, whilst high lights tend to become darker. Tissue paper stretched on the back of a negative, and a limited use of the stump, will be found to be powerful aids to the production of an artistic picture.

An artistically educated photographer instinctively sees the most favourable aspect of the subject he may wish to delineate. When he perceives that he is in a favourable situation, the camera should be erected, and the minor details of the composition must be attended to. Then it is that he must exercise to the full extent his artistic knowledge. Knowing the position his principal subject should occupy in the plate, he must note the different

subordinate objects that are also seen on the ground glass of the camera. If the subject require figures to be introduced to give 'forte' points he should note where, and how, they should be arranged. He should also note the most favourable time of day for taking the view, bearing in mind that one of the chief charms of a picture is a proper massing of light and shade, which as a rule can only be secured by sunlight falling across the picture, and not coming from behind, or from the front of, the camera.

As regards the absolute manipulation of the camera there is not much to learn beyond following a few simple rules. After selecting the view, the angle which is to be taken in should be roughly measured, and the lens selected accordingly. When this is determined, the view should be brought approximately on to the ground glass of the camera. It requires a certain amount of practice to form a correct pictorial estimate of an inverted image, and it is probable by turning the head in such a position that the line joining the eyes is nearly vertical, a more correct idea can be formed than by keeping it in the usual position. At first no diaphragm should be in the lens, as the general sweep of light and shade can be better studied. When this is satisfactory and the lines of the picture are the best that can be obtained, a diaphragm may be inserted with an aperture of the largest size which will admit of a good general focus being obtained. The object of interest must, however, be that which is most sharply defined on the ground glass, and it is sometimes advisable to sacrifice the sharpness of the other portion in order to attain this, and when the character of the sweeps of light and shade are not as good as could be desired, it may also sometimes be necessary to adopt this artifice to secure the proper attention of the eye to that point. It is not intended to imply that a picture out of focus is more artistic than one sharply defined. Though the eye sees only one portion of a landscape at a time in

focus, the remaining portion being blurred, yet, be it remembered, the photographic print, when properly viewed, occupies the position of the natural landscape, and the same difference of focus away from the object of interest takes place naturally; and, in the photograph, as in nature, the eye may wander to the points of lesser interest, and still find a charm in the minute details.

One of the essential suppositions of perspective is, that the picture plane should be vertical and the line of sight horizontal. Nevertheless, in focussing a landscape taken merely for pictorial effect it usually does not signify whether the camera be tilted downwards or upwards, or whether the ground glass be vertical, so long as the top and bottom of the pictures are parallel with the horizon line, though in architectural subjects, as we shall presently see, these points cannot be neglected. For a simple landscape, then, it will be found that the power of obtaining a good focus is well within the hands of the operator. From what has been already said at p. 197, it is seen that the focus of near objects is longer than that of more distant; thus, without using a diaphragm, the focus of the foreground will be longer than that of the middle distance, and this again than the distance. By using the swing-back, to cause the top of the ground glass to swing outwards, this is often secured. Again, on one side of the picture a near object may have to be represented; by using the horizontal swing, it may often be brought into focus. By the use of the vertical and horizontal swings together, it is sometimes possible to employ a much larger diaphragm than could otherwise be done. In landscapes this is often important, as a large available aperture to the lens means short exposure; and where the operator is exposed to the caprices of gusts of wind, the success of a picture is often dependent on the rapidity of exposure. As regards the tilting of the camera, latitude is allowable in landscape work. When the swing-back is used it is better to have a tilt downwards than to keep it level, as by so doing the plate is

kept more nearly vertical than would otherwise be the case. A tilt upwards exaggerates the distortion, and it is better to raise the board carrying the lens of the camera than to give it a tilt in this direction. Raising the lens board means taking off a portion of the foreground. This has the same effect as tilting the camera, though without causing the direction of the axis of the lens to be altered. As a general rule, however, tilting should be cautiously and sparingly used, otherwise it is apt to suggest that there is something wrong about the picture.

When the best general focus has been obtained by the above artifice, the diaphragm should be inserted so that the necessary amount of sharpness may be obtained, recollecting that the brighter the image, the greater will be the vigour of the resulting negative. When great contrasts in light and shade are in question the introduction of a small stop may sometimes be advisable, as will be evident by consulting the next chapter.

In focussing architectural subjects, where it is of importance to preserve the parallelism of vertical lines, the sensitive plate must *always be kept in a vertical plane.* In case the axis of the lens has to be tilted the swing-back must be used till this is attained. When this vertical plane is not adhered to we shall have the vertical lines which are parallel in nature converging in the picture. If we look at a cube lying on a horizontal plane the feeling to the *eyes* is that the vertical lines are parallel (perhaps because the most natural position for natural movement of the axes of the eyes is in a horizontal rather than in a vertical plane); if, however, we tilt the cube the impression at once vanishes, and they will seem to converge. Hence, to give the idea to the mind that an object is standing on a horizontal plane, the vertical lines must appear parallel to the eye, whether seen in nature or seen in a picture. Now, it can readily and easily be demonstrated that by tilting the camera without using the

swing-back, vertical lines must converge, hence the resulting picture would be untrue. It will perhaps aid the student in regard to the use of the swing-back to remember that for theoretical purposes the lens, whether its axis be tilted or not, may be replaced by a pin-hole in an opaque card, and that the image received through the pin-hole must be theoretically correct when received on a vertical plane.

As regards the exposure to be given to a picture there is one golden rule to follow: 'Expose for the shadows and let the lights take care of themselves,' that is, the detail in the shadows must be developable. By the judicious use of different developers, page 67, effects may be given which would be unattainable were one formula alone to follow. Thus, if the picture be full of great contrasts in lights and shades, a strong developer swept over the plate, carrying into the sink the greatest part of the free nitrate of silver, will lessen the difference between them; whilst a weak developer, of which none is allowed to flow over the plate, is most suitable when the contrasts are little. Again, even during exposure something may be done to give harmony to the negative by shading the lens with a piece of blackened card from those parts, such as the sky and clouds, which are most quickly impressed on the plate.

As regards portraiture the variations in lighting that can be produced in a well-appointed studio are so various that it would be impossible to treat of them in a limited space. For outdoor portraiture an angle of a wall facing the north with a background formed by a blanket is suitable for producing pictures that can be vignetted.

Indoor portraiture can be attempted where a window with a northerly light is available, and where white screens are at hand to lighten up that portion of the face which is in shadow. Ordinarily the principal light should make an angle of about 45° with the vertical and horizontal planes which intersect in the axis of the lens.

The student should refer to 'Pictorial Photography,' for

a comprehensive description of what to do and what to avoid. The rules given for landscape photography, however, in a great measure apply, particularly paragraphs 3–5, 7–10.

CHAPTER XXXII.

ACTINOMETRY.

Amongst the earliest methods of comparing the chemical energy of different lights is that known as Bunsen and Roscoe's, its value having been originally pointed out by Professor Draper, of New York. The process is dependent on the fact that combination takes place between hydrogen and chlorine when the mixed gases are exposed to the action of light. The two gases may be evolved by the electrolysis of hydrochloric acid, and then they are in the right proportions for recombination. Such a mixture of gases, when exposed to sunlight, combines with explosive violence, though in diffused light the recombination takes place gradually, and in proportion to the intensity of the light, and to the time during which they are exposed to it. This affords a method of securing a registration of the intensity of the light, for the hydrochloric acid formed may be collected in water, and the amount may be estimated by various chemical means. As for general use this method did not prove altogether satisfactory, and Bunsen and Roscoe abandoned it for one which will be described in detail. Professor Draper had also pointed out that ferric oxalate when exposed to light, gives out carbonic acid, and, in 1859, Mr. H. Draper, of New York, turned this fact to practical use by elaborating a system of which the following is an outline.

The chemical reaction on which the method is founded is this :—

$$\text{Ferric oxalate} = \text{Ferrous oxalate} + \text{Carbonic anhydride.}$$
$$Fe_2 3C_2O_4 = FeC_2O_4 + 2CO_2$$

The light vibrations are able to split up the ferric oxalate molecules, and for each molecule so shaken, one molecule of carbonic anhydride is liberated. Mr. H. Draper's apparatus consisted of 500 grains of a standard solution of ferric oxalate held in a glass cistern, rendered opaque by japanning, the light being admitted by leaving uncovered one square inch of the cistern. After exposure to the light for any desired time the amount of carbonic anhydride disengaged was known by the difference in weight before and after exposure, the loss due to evaporation being checked by comparison with a similar cistern containing distilled water. There are one or two objections to be noted as regards the accuracy of this method. The ferric oxalate being a coloured solution, it is uncertain to what depth the light penetrates into it, and it has yet to be proved that with equal intensities of light acting for the same time through the *same* aperture, double the same amount of chemical decomposition is produced after passing through two units of thickness, as is produced after passing through one. In all apparatus of this kind, too, the surface reflection has to be taken into consideration, as also the material of which the transparent parts of the cistern is constructed. If we could be assured that the value of the ultra-violet rays increased in the same ratio as the blue rays, the apparatus would suffice, but we have reason to think that this is not the case. Hence this construction must be taken as yielding an approximation to the true results rather than as the true results themselves. We consider that the best results would probably be attained by throwing certain definite portions of the spectrum on some medium, and noticing the results of each. This would give a true idea of the relative amounts of photographic energy existing in each

portion. It cannot be too deeply impressed on the student that these processes do not measure the *actual* energy in the impinging rays of light; this is altogether a different matter, into which we cannot enter here.

Professors Bunsen and Roscoe conceived the first practicable method of measuring the actinism of daylight and sunlight, by the exposure of sensitive silver chloride paper to their action for certain lengths of time. After an elaborate investigation, they came to the conclusion 'that equal quantities of the intensity of light into the time of insolation (exposure) correspond, within very wide limits, to equal shades of darkness produced on chloride of silver paper of uniform sensitiveness.' Starting with this idea they carried out a laborious research into the preparation of a paper that should be uniformly sensitive, and which might, therefore, be considered as a paper of standard sensitiveness. The following is a short *résumé* of their work: Choosing sodium chloride as the soluble chloride, they found, 1st, that a paper will not give uniform results when simply floated on the solution; but that it must be immersed in it. 2nd. That the stronger the solution the greater sensitiveness would be given to the paper. It was, therefore, necessary to fix some reasonable limit to the strength, and this they fixed at a 3 per cent. solution. 3rd, that using the sensitising solution of silver nitrate above a greater strength than 6 per cent. gave no difference in the results as regards sensitiveness, but that below that strength it rapidly diminished. 4th. That the presence of the salt resulting from the decomposition of the sodium chloride and silver nitrate had no effect on the sensitiveness, and that at ordinary temperature and moisture the sensitised paper would keep at least 15 hours unaltered. 5th. That the thickness of the paper employed had no material influence on the result—an important point, as in comparing the darkening due to the light with a standard scale of graduated tints it was necessary that the paper should be suffi-

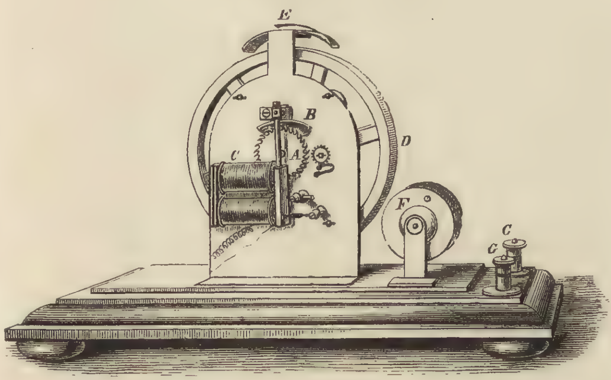
ciently opaque to cut off all shade from the tint beneath which might shine through the paper. 6th. It was found that it was possible to impregnate 5 square metres of paper in a solution containing 60 grammes of sodium chloride without any danger of reducing the strength of the solution to such a degree as to cause any variation in sensitiveness. 7th. The time of sensitising, between 15 seconds to 8 minutes, also caused no alteration in the readings.

It will be noticed that the above results give great latitude in preparing a paper, the only conditions absolutely necessary being that the paper shall be uniformly soaked with a 3 per cent. solution, that the sensitising bath of silver nitrate shall not be suffered to drop below a 6 per cent. solution, and that the sensitising shall not be less than 15 seconds of time. With such a preparation we have then a standard paper which will give uniform results —that is, we have a paper, which, when exposed for a certain time to a certain intensity and *quality* of light will always produce the same amount of darkening. The most perfect method of measuring intensity of daylight, then, would be to cause a strip of sensitive paper to pass gradually before an opening of a certain size, such opening to be exposed to the zenith. Unfortunately, this method is impracticable; for, as we shall find shortly, the darkening action in strong light, such as we have in sunshine when the sun is in the meridian, is exceedingly rapid; whilst in weak light, such as we have on a cloudy day, the darkening is exceedingly slow. It might be suggested that the opening should be wedge-shaped, so that the shade itself might be graduated and therefore be readable at some part, and at a very early date in the history of photography this plan was proposed by Mr. Jordan; but practically it is found that the opening necessary for the production of a readable tint in full sunshine, with paper passing slowly before it, is so small, that there are mechanical difficulties in the way of securing accuracy; and when it is considered that one end of the

aperture would have to be at least 100 times the width of the other, the impossibility of obtaining a proper gradation with a slip of paper of reasonable width is apparent. To meet this difficulty a most ingenious instrument has been devised by Professor Roscoe, in which exposure takes place for certain regulated times, at fixed intervals, during every hour.

The registration is effected by the following contrivance: Fig. 83.

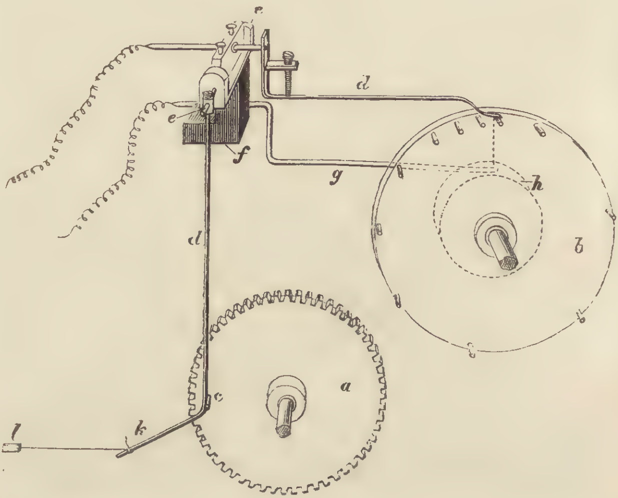
FIG. 83.



A long strip of paper is rolled upon F, and fastened to D. In the latter is a clock-work arrangement, the escapement, B, being placed as shown. To move the clockwork, the armature of an electro-magnet takes the place of a pendulum, and every time it is attracted and released by the magnet, a tooth of the wheel is released, and the paper is moved a small piece forward across the weak spring, E, which is seen on the top of D. The use of the spring is to cause the paper to be in contact with a circular aperture of about $\frac{1}{4}$ inch in diameter, left in the cover of the instrument, and through which the exposure is given. The result of the exposure is thus to leave circles of more or less blackness (the blackness varying according to the intensity of the

light and the time of exposure) at intervals along the strip of paper. These intervals and durations of exposure are controlled by the accompanying piece of apparatus, which forms part of a clock.

FIG. 84.

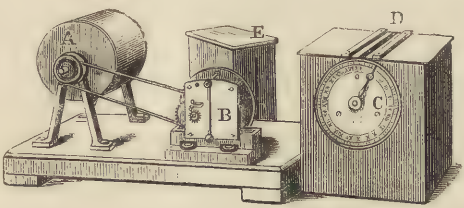


a is a toothed wheel belonging to a clock, revolving once every hour, in one part of which a peg, *c*, is inserted, and so placed that the lever, *d*, is in contact with it for about two minutes ; *b* is a disc with platinum points placed at differing intervals, and revolves once every two minutes. The lever, *d*, is caused to press on these points by a weak spring ; *l* is an ebonite insulating block, to which the two levers, *g* and *d*, are attached as shown, which are in connection with the terminals of a battery. When the pin, *c*, presses against *d*, and when it is in contact with the pins on *b*, a current traverses the circuit, in which is introduced the electro-magnet, C, of fig. 83. By this arrangement when the armature of the electro-magnet is attracted and released by the passage of

the pins on *b* across the end of *d*, the paper moves on a small portion, and the exposure takes place for the time corresponding to the intervals between the pegs. When the peg, *c*, is not in contact with *d*, a lengthened exposure is given, and this marks the hour intervals. *e* is a cord attached to *k*, which can be used to cause exposures, at any time that may be desired. This is useful when adjusting the instrument, and for determining the interval of time which elapses between the passage of the several pins.

Another instrument for attaining the same end was devised by the writer on a different plan :—

FIG. 85.



A cylinder, A, round which is placed sensitive paper, is connected by a strap with a small French clock, B, and the diameter of the pulley is so adjusted that the clock causes the cylinder to rotate in 25 hours. If it were absolutely certain that the paper would be removed at the same hour, it would be more convenient to cause the cylinder to revolve once in 24 hours; the extra hour is allowed for any irregularity that may occur in the removal of the paper. A cover, C, fits accurately over the cylinder, and in it is a slit, D, $\frac{1}{8}$ inch broad, which is covered by a wedge, the process of graduation of which will be subsequently given. One end of the wedge allows nearly all the light to pass through it, whilst the other is nearly opaque. Over one end of the cylinder is placed a cap, fitting over the paper, in which are slits, corresponding to the 25 hours. When the

cover, C, is placed over the cylinder, and the cover E over the clock (to prevent the access of rain or dust to the works), the apparatus is placed in the daylight, the wedge approximately running from east to west. As the light acts on the sensitive paper, a graduated darkening takes place, and through the brass cap on the end of the cylinder the time at which any particular exposure takes place is noted by the light itself. When the wedge is properly graduated some part of the band is always readable.

In the first instrument a wedge was made of nearly black glass, having, however, a *slightly* green tint. Had it been pure black, equal lengths of the wedge would have given equal lengths in the scale of blackness. For, if A be the intensity of the light impinging on the wedge into the time of exposure, and A′ be the intensity of the light after passing through the thickness of any part of the wedge into the time of exposure, x be the thickness of the wedge, and μ a co-efficient due to the absorption of light by the wedge that

$$A' = A\epsilon^{-\mu.x}$$

ϵ being the base of hyperbolic logarithms. This was found not to hold good unless the light were monochromatic, the reason being evidently due to the different coefficients of absorption of the rays which passed through the wedge. To remedy this defect, recourse was had to photography. A dry plate was exposed to the action of light beneath the wedge and developed ; a black tint was secured by employing a platinum salt as the toning agent, and the results thus obtained were satisfactory, any actinic light giving the same relative readings. In some cases the platinum was burnt into the glass, but no great gain was found in so doing.

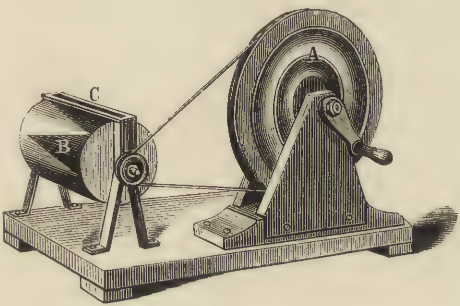
The following is the standard tint of grey adopted by Roscoe. He took 1,000 parts of zinc oxide and 1 part of lamp-black, and ground them thoroughly together to such a point that no further grinding altered the tint. This he found the most convenient tint for comparison ;

and, when carefully gummed on to paper, it was unaltered in shade. This mixture then gave the shade from which all his measurements were made, all other tints being referred to it.

To obtain a graduated shade he applied what is known as the pendulum apparatus, which in general outline consists of a pendulum swinging in front of sensitised paper in such a manner as to give a gradation of exposure to it, and a consequent variation in tint. At each point of the paper the time of exposure was known, and the point was then found answering to the standard tint, and the relative values of the other portions of the gradations calculated.

It may perhaps be found necessary hereafter to apply a correction to those readings taken in sunlight, as it may be found that the different integrations of the spectra formed by sky, cloud, and sunlight produce slightly different effects.

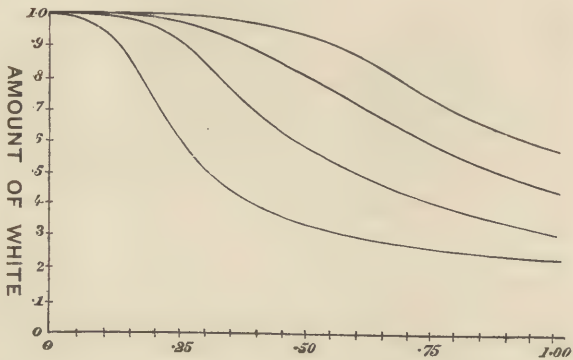
FIG. 86.



Another method of securing uniformity in measurement has been employed by the writer. It consists of a rapidly revolving cylinder, or drum, B, on which is attached a series of black and white sectors, as in the diagram. A convenient length for this drum has been found to be 6 inches. To the cylinder, B, is fixed a small pulley firmly attached to one end, over which is passed a cord communicating with the

wheel, A. These are of such relative dimensions that the cylinder rotates at least 15 times in a second, when A is caused to rotate but once. Along the top, and nearly touching the cylinder, is a blackened brass support, C, with a slot in it, on each side of which is a scale of inches, dividing the length of 6 inches into 120 parts, that is, each inch into 20 parts. Monochromatic light is thrown vertically downwards, on the scale, and any tint to be compared is brought on to the scale, and moved till an exactly identical shade is found on the rotating cylinder. A series of 6 readings is taken, beginning by moving the tint from white to black, and next from black to white. It will nearly always be found that this is necessary, as the readings in one case would be as much too high as in the other they would be too low. A mean of the six gives very nearly the truth. The accompanying diagram gives the results of the reading of a strip of paper which had been exposed beneath an apparatus, giving an arithmetical progression of exposure for each unit of length :—

FIG. 87.

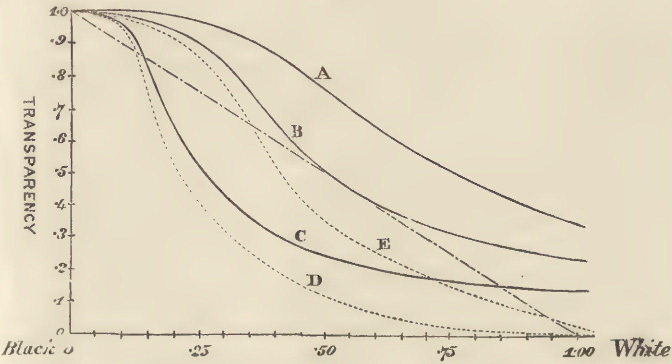


The ordinates measure the amount of white, 1·0 being white, and 0 black. The abscissæ show the exposure, with a

fixed intensity of light. From a curve of this kind, when the tint is compared and known, and the time of exposure is also known, the intensity of the actinism can be judged. Roscoe's standard unit has an ordinate of ·76, that is, it is a visual combination of 24 parts of black with 76 of white: —

This method of examining the gradations caused by different intensities is well worthy of more complete study, as it throws much light on the false effects which are produced in photographs. If we prepare a rotating wheel with black spokes so cut that when rotating in front of a uniformly lighted surface they give the exposure along the length of the spokes in arithmetical progression (thus: if the length of spoke be 10 inches, the exposure at that distance is 1, at 5 inches $\frac{1}{2}$, at $2\frac{1}{2}$ at $\frac{1}{4}$, and so on), we shall find, on exposing a plate to the image of this rotating wheel as formed by a lens, or by causing the wheel to pass close to it, that the gradation of the negative obtained, when viewed by transmitted light, will not coincide for any length with the gradation as seen by the eye. The following figure

FIG. 88.



shows the results of measurements obtained by the diaphanometer,[1] from plates to which different exposures

[1] See *London, Edinburgh, and Dublin Phil. Mag.* Sept. 1874.

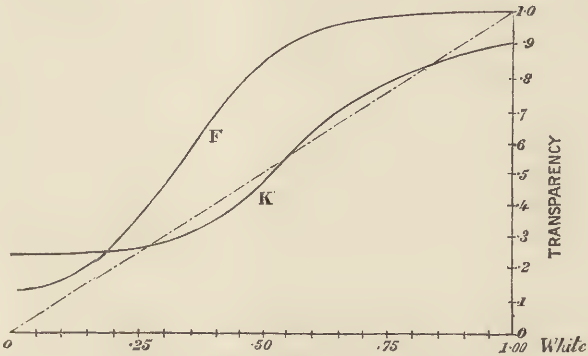
have been given behind the rotating wheel. A, B, and C are the curves from simply developed negatives. The ordinates measure the amount of transparency, 1 being total transparency, and 0 total opacity; the abscissæ denote the relative times of exposure, or what is approximately equivalent to it, the relative intensities of light acting on the negative, supposing Roscoe's law referred to above to hold good. It will be seen that the curves have very nearly, that is, within the limits of error of observation, the same form. Thus, taking the exposure of A equal to ·5 and 1, or 1 to 2, the corresponding transparencies are ·77 and 37·. Taking the same transparencies of B, the times of exposure are ·34 to ·66, or very nearly 1 to 2. The same will be found with C; the dotted curves, E and D, show a portion of the negatives, B and C, intensified in the ordinary manner, and the same relation to exposure still holds good. This is an important point, as it shows that the same relative intensities of light are maintained in a negative, as the opacity is increased. The ordinates to the chain-dotted straight lines show the transparency that should result if photography gave perfect gradations. It will be seen that the tendency in all negatives is to cause a loss of gradation in the deep shadows as well as in the lights. This accounts for the loss of detail that is always seen in the extreme tints of a photograph. It is also worthy of remark that a thin negative seems to give a better gradation than one intensified.

It must be distinctly understood that the above curves apply to negatives only under one class of development. Under others the curves would show considerable variations. Amongst the most striking would be the form they take when near the parts in which total transparency is represented. A more detailed account of these will be found in the 'Photographic News,' for July and August, 1877.

As an extension of the foregoing we may describe what happens in reproducing a negative in the camera or by

contact. The first method is often not so absolutely true as the latter, owing to the defects that a lens of necessity introduces; but as regards the shades the same results hold good. In the accompanying figure F and K are two curves, representing transparencies taken from the negatives D and B in fig. 88. These two negative curves have been selected as showing the results obtained from a simply developed and also an intensified negative. It will be noted that the curve K follows the line representing the correct gradation more

FIG. 89.

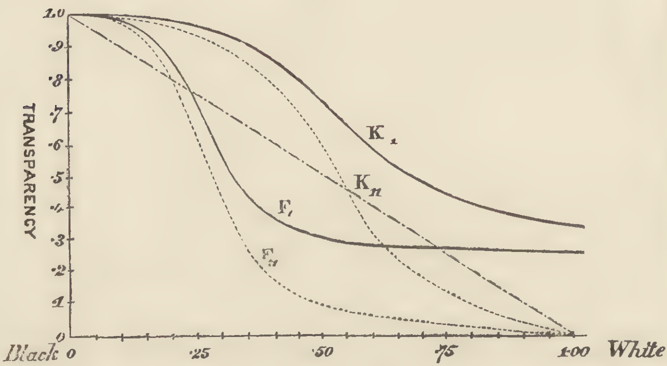


closely than the curve F. Had K been intensified it would have shown greater curvature, and could not have conformed so nearly as it does to the dotted line. Hence we may infer that a thin positive from a thin negative more closely represents true gradation than if either or both of them be intensified. The theoretical curves coincide tolerably with those obtained by measurement. It must be noted that in the curve K no portion is absolutely transparent. The exposure has been so prolonged as to cause a slight veil. It will be seen that for the reproduction of a negative this is no detriment. In fact, it follows the usual practical precept laid down that a transparency should show little or no bare glass.

The next figure shows the production of a negative from

the transparencies represented by F and K in the previous figure. K_1 is a curve showing the simple reproduction of K by development alone. K_{11} shows the same intensified, so that it possesses opacity at one extremity. F_1 and F_{11} represent F under the same conditions. The ordinates to the strong curves show the amount of transparency, whilst the ordinates to the chain-dotted lines, as in the two previous figures, show the amount of white in the original gradation. If we compare B with K_1 and K_{11}, and D with F_1 and F_{11}, the immense deterioration that has taken place in the truth of the gradation as represented by the reproduced negative will be

FIG. 90.



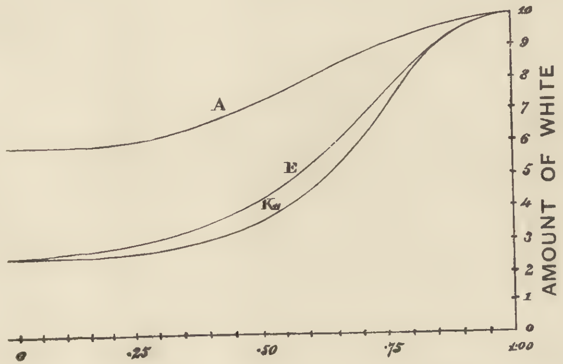
apparent. Another reproduction from any of the curves K_1 K_{11}, F_1 F_{11}, would still further increase the falsity, till after a few more reproductions the shades would have nearly entirely disappeared, and we should have a negative represented by a large portion of entire transparency with an abrupt change to total or nearly total opacity.

It is thus evident that in the reproduction of negatives the greatest care is required to keep approximately true gradation in the transparent positive as well as in the original negative; this can only be obtained by keeping both as thin as is practically possible. This fully accounts

for the loss of delicacy that is so often seen in reproductions and enlargements, and it seems impossible that the same harmony can exist in them as in the original, supposing the latter to be capable of giving a good print. It may be possible to obtain a fair reproduction of a negative if that 'positive' transparency be very thin, and there is no doubt that such reproduction can furnish excellent prints, but if placed side by side with prints furnished by a fairly intensified negative produced by the first operation, there will be a marked inferiority in the former.

It may not be uninteresting to finish this portion of our subject with a diagram showing the character of the gradation of the prints that would be obtained from the negatives A, E, and K_{11}; in each case the hypothesis will be made that no perceptible tint is printed through the most opaque portion of the negatives.

FIG. 91.



For ordinary photographic purposes actinometers are required, but their use being confined to the purpose of approximately measuring the exposure to be given to either a sensitive plate, or a sensitive printing surface, their accuracy need not be so great as those already described. In printing

carbon tissue, Chap. XXIV., the opaque and usually dark pigment effectually prevents the change effected in the chromated gelatine by its exposure to actinic light from being observed, and in this particular instance, as also in the photo-engraving, and its kindred processes, an actinometer is absolutely necessary. The simplest form consists of a long slip of sensitive albuminised paper, coiled in a small tin box, in the top of which is cut a slit. On each side of the slit the tint which the paper assumes after a certain exposure is painted. When a carbon print is exposed the actinometer is placed side by side with the printing frame in the light, and when the sensitive paper in the former has assumed the colour of the painted tint, a fresh portion is exposed, and so on, till it is judged that sufficient depth of printing has been given to the carbon tissue; the number of tints required of course varying with the intensity of the negative.

Another form of actinometer is formed as follows: Strips of oiled silk or coloured paper, which are only partially transparent to the actinic rays, are cut into diminishing lengths. These are pasted one upon another, so that at one end there is only one thickness of material, at (say) a quarter of an inch from that only two thicknesses, and so on, till at the other end, there are a dozen thicknesses. The number of thicknesses is painted in black on these 'steps' and the actinometer is complete. If the light were uniformly cut off by each strip, an exposure giving the same tint beneath the gradually increasing thicknesses would be in a geometrical series; as it is they progress in a very complex manner, but after a little experience, a good estimation of their value can be formed. To use the actinometer, sensitised albuminised paper is exposed beneath it, and the tint judged by noting the last figure which can be read on the exposed surface. An improvement on this actinometer might be made by taking a graduated strip of glass as described at page 254, crossed at intervals with black lines which should give an arithmetical series of exposures.

CHAPTER XXXIII.

PHOTO-SPECTROSCOPY.

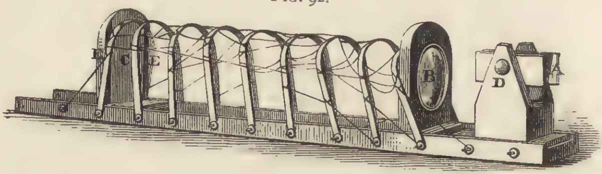
One of the branches of science into the service of which photography has been impressed is that of spectroscopy, and the aid it has given dates from nearly the early days of the daguerreotype. In the researches at present made with the spectroscope it plays such an important part, that a rather detailed description of the apparatus necessary and the methods employed will be given.

Photo-spectroscopy, however, has two aspects: in one it is the study as to the sensitiveness of compounds to the in fluence of different portions of the spectrum; in the other, the study of the spectrum itself. The first may be considered an essential preliminary to the second, and will therefore be examined first.

Becquerel, Herschel, Draper, and Hunt are the names of physicists to whom is due a great part of the knowledge possessed up to the present date as regards the different degrees and extent of impressibility which a variety of compounds show. In the loan collection of scientific apparatus was exhibited the instrument with which Herschel made his various researches. His experiments were undertaken before the days of the collodion process, and his *modus operandi* consisted in giving washes of one or more solutions to paper, and then submitting the sensitised paper to the solar spectrum. The accompanying figure (p. 264) gives an idea of the prismatic arrangement he adopted. A is a flint-glass prism, capable of turning on an axis, D; B a lens of about 24-inch focal length; C the screen on which the sensitive paper was placed. The sunlight was reflected by a mirror into the prism, the image of the sun after passing through A was elongated into a spectrum, and

brought to a focus on C by means of the lens B. One portion of the spectrum was caused to fall on the line, E E; the particular ray being found by examining the spectrum by means of a piece of cobalt glass, which cuts off all rays excepting two. The cage was covered with a black velvet cloth. It will be noticed that no slit was employed, but that the spectrum was really formed by a series of overlapping images of the sun. The spectrum was thus of necessity an impure one, and in the results obtained with it this has to be taken into consideration. For a detailed account of the experiments carried out by Sir John Herschel, the 'Philosophic Transactions of the Royal Society' should be consulted, and also 'Hunt's Researches on Light.' The registration of the Fraunhofer lines of the

FIG. 92.



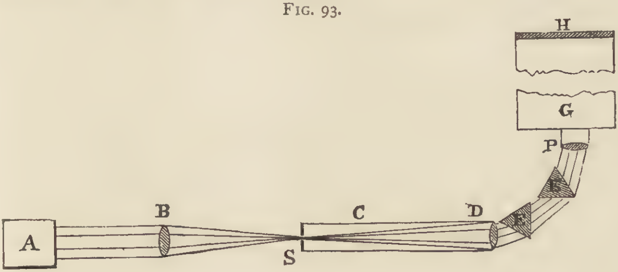
solar spectrum was effected by Becquerel and Draper with an instrument similar in general principles to that which will presently be described. Both of these eminent physicists employed the Daguerrean process with the greatest success in these researches. The latter performed the feat of registering the lines in the least refrangible portion of the spectrum by the reversing action of the red rays, of which a description will be given subsequently.

An apparatus that will answer the purpose for a student will now be described. The great essentials are good prisms and a collimator of fairly long focus. These may be purchased separately from an instrument-maker, and fitted up by the operator, if he be at all handy with ordinary carpenter's tools. Thus the collimator tube may be supported in a

cradle, and the prisms mounted on a block of smoothly-planed wood, or a slate slab, so arranged that the axis of the lens of the camera is of the same height as the centre of the prisms, as is also the axis of the collimator.

The accompanying arrangement shows the manner in which a temporary photo-spectrum apparatus can be fitted up. A is a heliostat, throwing the sun's rays into the condenser, B, by which an image of the sun is formed on the slit of the collimator, C. The lens, D, of the collimator is so placed that its equivalent focus falls accurately on the exterior of the slit. This should be obtained by trial, and it is very advisable that the slit arrangement should be attached

FIG. 93.

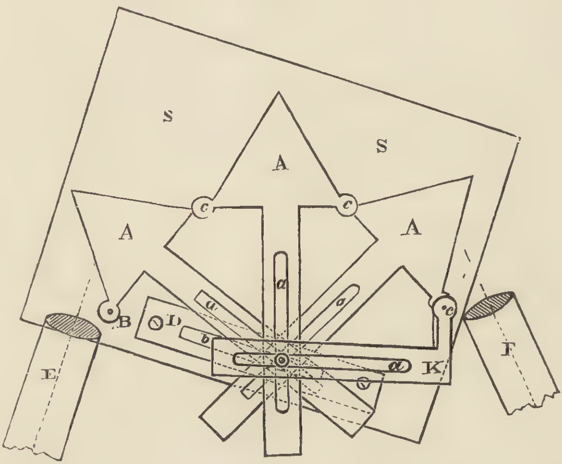


to an inner tube, which can slide in that to which the lens is attached. The rays proceeding from the illuminated slit travel in such a manner that when certain requirements, which will be entered into presently, are fulfilled, the lens of the collimator is perfectly filled, or at all events the rays of light form a central disc on the lens, D. The light then travels to the prisms, E, by which it is refracted and dispersed, and then it reaches the lens, F, of the camera, G, by which lens the spectrum is thrown on the plate, H, where it is focussed. As difficulties frequently arise at first in the adjustment, &c., of the apparatus, a few hints may not be out of place. In order to secure good results the focal length of the condensing lens, D, when

divided by its diameter, should never exceed the length of the collimator when divided by the effective aperture of its lens. Should it do so, it will be seen that the collimating lens will be more than filled, and reflections from the sides of the tubes might interfere with definition. Again, it is useless to have prisms which cannot receive all the rays proceeding from the collimating lens. Their height should therefore, be at least equal to the effective aperture of the collimating lens, and the faces should be longer, since they are placed obliquely. In all cases the centre of the mirror, the axis of the condensing lens, and of the collimator should be in one straight line. To effect this, it is better at first to remove the condenser from the train of apparatus. The image of the sun, when thrown on the slit, should give a bright diffused line occupying the *centre of the collimating lens*, D. The position and height of the heliostat must be changed till this is obtained. The condensing lens, B, may now be inserted and moved till the rays of light form a circular disc, filling the centre of the lens, D, when a sharp image of the sun is thrown on the slit. When this is obtained the prisms may be placed in position. By the aid of an ordinary small telescope the angle of minimum deviation may be obtained. Suppose it is required to photograph the portion of the spectrum about the line G. The prism would be placed roughly in position, and that line would be observed. It would be found that by turning the prism in one direction, the line would appear at first to travel in one direction, but that when a certain point was reached it would begin to travel in the opposite direction. The position the prism occupied when the change in direction of the apparent motion of the line took place would be the position the prism should occupy, in order for that particular ray to be refracted in the angle of minimum deviation. The reason why this angle is of consequence must be sought for in books specially devoted to spectroscopy. It is sufficient to note that in any other

position the true breadth of the absorption lines would not be obtainable. The next prism may be adjusted in a similar manner, and so on for the others. Finally, the camera and its lens should be so placed that the ray for which the prisms have been adjusted should occupy the centre of the focussing screen or sensitive plate. It

FIG. 94.



may be noted that four prisms of 60° will generally cause the axis of the camera to cross the axis of the collimator.

Another contrivance[1] for always securing the minimum angle of deviation is shown in the accompanying diagram. Cut out, in stout card or brass, pieces having the form A A A, also D and K. Care must be taken that the bases of the triangles are of uniform lengths, and slightly longer than the base of the prisms, which should be of uniform angle, and preferably of equal size. D should be let into the board S S, so that its top surface is flush with it, and there should be a groove cut beneath the slot, *b*, to allow a pin, of a diameter

[1] The principle of it is due to Mr. Browning, the optician.

equal to that of the slot, to travel along it. The slots *a a a* in A A A and K are also placed over the pin. The first triangle is attached to the board, S, by a pin at B. The remaining triangular portions, and also K, are attached to each other at *c c c*, and are free to move over the board S. The axis of the collimator is placed at right angles to the slot, *b*, and, by touching K, the arms from the triangular portions move about the pin, the slots, *a a a*, guiding the motion at the same time the parts move separately about *c c c*, and the whole system turns about B. It will be seen by this that each base of the triangle moves through twice the angle of the preceding one, as also does K. The direction of the line joining the point in K, answering to the middle point of the base of the triangle, and the middle point of the base of the adjacent triangle, determines the position of the axis of the lens, F, of the camera. Such a board may be used as a pattern by which to set the prisms for any particular part of the spectrum, or the prisms themselves may be set on the triangular portions, provided the board, S S, be perfectly plane, and that precautions be taken to raise by obvious means the prisms to the same level, and to cause the triangular patterns to be so adjusted that there shall be no deflection owing to their arms being at different heights on the pin. It will be found that two prisms of 60° and two of 45°, or three of 62°, will be the greatest dispersion that can be employed, unless special arrangements are made. As a guide to the length of spectrum that can be photographed at one time, it may be stated that with a lens to the camera of 120 centimetres focus, and using one ordinary flint prism of 60°, a photograph of about 10 centimetres is obtained; and with the same camera and two prisms of 60° the length of spectrum is about double.

To focus the lines accurately is somewhat difficult, for it will be found that the focus of the violet rays is shorter than that of the red. A fair general focus can, however, be obtained by using with the camera a vertically-pivoted

swing-back. It is usually prescribed that the focus should be obtained by placing a transparent glass plate in the place of the ground glass and viewing the spectrum by a high-power magnifying lens. This latter should be attached to a sliding tube, so that when the end of the tube is placed against one surface of the glass plate the other surface immediately opposed should be in the plane of its focus. By this means the rays which have to be focussed on the inner surface of the plate can be viewed by the magnifier, and the plate of glass moved backwards and forwards by the screw motion of the camera, till the lines appear sharply defined to the eye. Theoretically, this is a perfect method, but practically it fails if two portions of the spectrum which are far apart have to be photographed at one operation, for the necessary inclination of the surface of the glass away from a plane perpendicular to the axis of the lens (the deviation being effected by the swing-back), is so great that the axis of the magnifying lens is thrown completely out of the direction of the rays of light, and there is necessarily no image observed. The writer has found great advantage in cutting an opening across the top of the camera, pasting highly-glazed white paper on a piece of plate-glass, occupying the position that the sensitive film has to do, and by then focussing on this white surface through the opening by means of a small telescope.

When the focus is fairly obtained, the exposure of a few plates and a minute change in the focal distance will show which is the best position to choose for photographing any particular part of the spectrum. A good method of obtaining the correct distance of the collimating lens from the slit may here be indicated. Make an ink mark on a piece of glass, and focus it with a magnifying lens fitting in a draw-tube, taking care that the surface of the glass on which is the mark is next the draw-tube. Now place the magnifier against the plates forming the jaws of the slit (which should be rather widely opened), and view some

distant object through the collimating lens. When this appears quite sharply defined, the definition being obtained by altering the distance of the slit from the collimating lens, this adjustment is complete.

In the case of a lens only partially corrected, the focus may vary. In one position the image may appear perfectly sharp but surrounded by a blue fringe, and in another by a red fringe. When the most refracted rays are to be photographed, that focus should be chosen in which the red fringe is seen; whilst, if the least refracted, that in which the blue fringe is apparent.

It must be recollected that the greatest accuracy in all these points is requisite in order to obtain the best results.

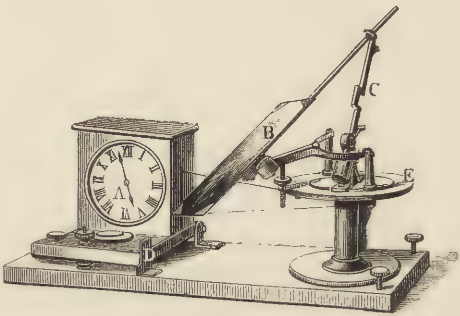
The examination of sensitive compounds other than silver is not so readily undertaken by the above arrangement, as the time of exposure to obtain a sufficiently marked result would be very prolonged.

A more convenient, though perhaps less exact, apparatus for examining these, where more dispersion than that given by one prism may be required, is the ordinary direct-vision spectroscope. It can be inserted in a small camera which is adapted for a lens whose equivalent focus is somewhere about 20 centimetres. With such an instrument there is only a collimating lens and no telescope for viewing the spectrum. In using it for photography, the distance between the lens and the slit can be altered, so that it may produce an accurate focus of the Fraunhofer lines on the focussing screen. It is better then to open the slit to such a degree that the lines broaden out. One or two distinguishing lines, such as the H and *b* lines, will still be traceable, and from these, and by a comparison with a picture taken on a silver compound, with a more closed slit, the limits of the spectrum impressed on the sensitive salt under consideration may be accurately obtained. For obviously, when the slit is say a millimetre wide, there is but little impurity in the spectrum. With this

apparatus, as in that above, it is advisable to employ a condenser.

For the student who studies this branch of photography a heliostat is almost a necessity, and the writer has found the form given in the accompanying figure, designed by Stoney, to answer perfectly when a little care is used. A is a small French clock, round the drum of which, and also round a small wheel fixed on the instrument, passes a cord. B is a mirror, held in position by a rod which slides in a pivoted socket at the end of C. C is attached to a part

FIG. 95.



which answers to the polar axis in an equatorially-mounted telescope, and it is to this polar axis that the driving-wheel alluded to is attached. It will be noticed that the clock stands on a board which is attached to the base board of the entire instrument. A level is fixed on this clock board, and the plane of the board can be caused to make a certain small angle with the base board by means of a screw adjustment. The amount of 'tilt' is indicated by the arc D. When the clock stand is levelled, a certain diminution or increase of angle to the vertical can be given to the polar axis. The instrument is placed in position as follows:— The polar axis is made to point to the pole, any small differ-

ence (say of 2 or 3 degrees) of latitude being adjusted by a small arc D. When the clock stand is levelled the polar axis will then occupy the required angle with the horizon. The method of securing a true north point for the axis will be apparent when the instrument is examined; for by making E, which is a circular annulus graduated to hours into a sun-dial, a north point, approximately correct, can be found. C is then placed at such an angle that the image of a small round hole, bored in a brass disc attached to its top, is seen to shine on a small ivory screen attached at its lower part. The graduated annulus, to which B is also attached, is then moved till the sun shines in any required horizontal direction. Vertical motion is given to the beam of light by using the screw shown in the figure.

CHAPTER XXXIV.

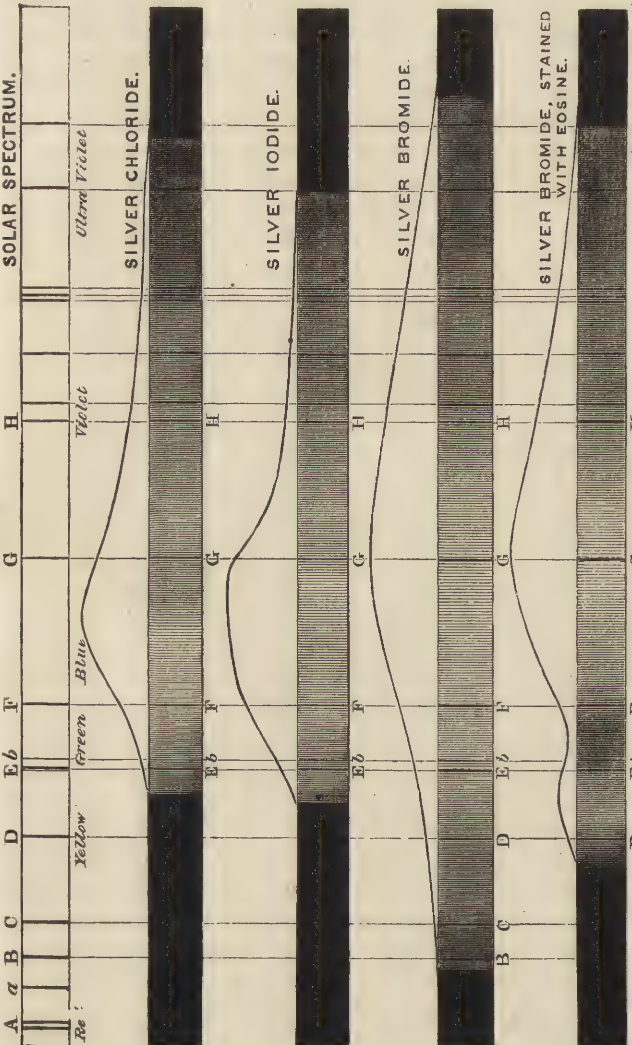
SENSITIVENESS OF DIFFERENT SALTS.

When the proper apparatus is in possession of the student, he should attempt to reproduce the results shown in the second, third, and fourth diagrams of fig. 96.

Silver Iodide.—When the spectrum is allowed to fall on silver iodide formed by the ordinary collodion process, it will be found that the maximum intensity is situated about the line G, and terminates far beyond the violet at one end, and about the line 'b' rather abruptly.

Silver Bromo-iodide.—When silver bromo-iodide is substituted for the silver iodide, the same kind of photograph is obtained by the collodion process. In this compound, and also when the silver iodide is employed as formed in the Daguerrean process, similar results are to be looked for. With this last process, however, different phenomena are

FIG. 96.



The curved lines show the relative effects cf the different portions of the spectrum.

observed when the plate has received a short preliminary exposure to white light, or when diffused light is allowed access to the plate during exposure to the spectrum. On developing such a plate it will be found that the red rays and those which are usually inactive on these salts, have exerted a negative or reversing action on the sensitive plate. On development, the diffused light will have impressed a lightish border to the whole of the spectrum, the blue and violet part of the spectrum will appear lighter than this border, whilst the least refrangible portion of the rays will have caused, what is apparently, an undoing of the work executed by the diffused light, leaving that part of the plate of its normal hue. Thus in the most refracted part of the spectrum the absorption lines due to the solar atmosphere will appear as grey on a lighter ground, whilst at the least refracted part they will be light on a grey ground. The process for producing these pictures has been given by Dr. H. Draper in the 'Phil. Mag.' Feb. 1877. This reversing action of the red end of the spectrum is one of the most remarkable phenomena to be met with in photography. Some recent experiments [1] made by the writer probably may throw some light upon this subject; though incomplete in some particulars, they yet tend to show that another action, entirely differing from that already described in the early chapters, may modify the capability of development of the photographic image. They show that the image can be rendered undevelopable by oxidation of the altered silver compound forming it. Thus if a sensitive film be exposed to light under proper conditions as to sensitiveness, the image becomes undevelopable by the oxidizing agency of potassium permanganate, chromic acid, and *ozone*. Chastaing has recently announced that he finds the red rays promote the rapidity of oxidation; hence, taking this as definitive, it is easy to see that the sensitive salt of silver which had been

[1] *Lond. Edin. & Dub. Phil. Mag.* Jan. 1878. *Photographic Journal*, Dec. 1877.

altered in chemical composition by a slight exposure to light would become oxidized, where the red light acted upon it, whilst where the dark Fraunhofer lines fell the salt would remain unaffected. Now it is most probable that the oxidation would be naturally aided by the colour of the altered compound; for from Chapter II. it will have been gathered that, in order to obtain a photographic action from any particular ray, it must be absorbed by the sensitive compound. Applying this rule to the case in point we know that bromo-iodide and iodide of silver darken or become bluer through the continued action of light. The colouration must exist in the individual molecules of the silver salt altered by light, though it may be indistinguishable, owing to the superior number of unaltered molecules.

With the bromide of silver the reversing action of the spectrum can also be made apparent. Waterhouse has done so in some of the spectra he has produced, by giving his collodio-bromide plates a slight preliminary exposure to diffused light. A more sensitive surface may be produced, however, by chemically producing a small proportion of silver sub-bromide in the collodion, and on exposure to the spectrum remarkable results are obtained, which as yet have only been partially examined.

Hunt, in his 'Researches on Light,' records a combination of potassium ferro-cyanide with silver iodide, which offered a very remarkable exemplification of this reversing action. Potassium ferro-cyanide is brushed over iodised paper where free silver nitrate has been applied, and the spectrum allowed to fall upon it. The blackening of the paper takes place with extreme rapidity, first in the violet rays, and then extending over the ultra-violet or invisible rays, and down as far as there is a visible spectrum. If removed as soon as the first darkening takes place, a *coloured* spectrum will be found impressed, the red rays impressing a red colour, and the blue rays blue. If the exposure be continued, in a short time a bleaching action

comes on the red, and extends upwards to the green. In the first action there is no evidence of any protective influence in the extreme red, but when the bleaching effect is set up, the space occupied by the extreme red ray is maintained perfectly dark.

The increased sensibility of this paper appears to depend on the joint decomposition of the potassium ferro-cyanide and the silver iodide. It is well known that potassium ferro-cyanide is decomposed by prolonged exposure to the sun's rays, with the formation of Prussian blue.

Similar results are obtained with silver chloride, though here the phenomena to be observed are still more marked. If paper be impregnated with sodium chloride, and be then floated on silver nitrate, and exposed to the action of the spectrum, it will be found that the visible impression made is that shown in the figure, page 273. If, however, the paper be exposed to light till it assumes a lavender-grey appearance, and be then exposed to the spectrum, a change will appear. The part exposed to the red rays assumes a brick tint approaching to red, the green assumes a green ashen hue, whilst the violet and blue have the same tint as is usually seen. On taking such a print, and developing with gallic acid and silver nitrate, as in the calotype process (p. 131), evidence of molecular change in the part that has been exposed to the red rays will be apparent, the developable spectrum in this case extending as far as B. In the effect produced by white liquid on ordinary sensitised paper, this action of the red rays must be taken into account.

When chloride of silver is suspended in collodion, and used in an emulsion in the same manner as silver bromide, like results are obtained, only in a more marked degree, the tints assumed being of a much more brilliant hue. The subchloride may be altered in composition, as indicated above. The visible coloration is generally supposed to be due to the same cause as is the colour of thin plates, but

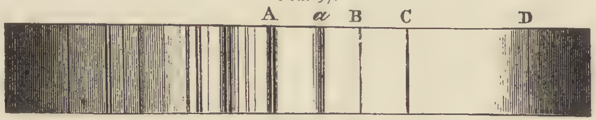
some preliminary experiments seem to show it may be due to the different stages of oxidation of the metallic salt; but this cannot be pronounced with certainty, till some of a more detailed and confirmatory character, which are at present in progress, have been completed.

Becquerel produced coloured photographs of the spectrum on silver subchloride, which he produced by chemical means, using silver plates as a support. By immersing a silver plate in hydrochloric acid, attached to the negative pole of a battery, and opposed to a platinum plate, attached to the positive pole, the subchloride was formed. The surface of subchloride was exposed to the spectrum, which was allowed to print itself on it. Some beautiful examples of these spectra have been exhibited at Paris, and also in London at the Loan Exhibition of Scientific Apparatus. Niépce de St. Victor further extended this method to obtain coloured photographs of dolls dressed in coloured clothes.

A consideration of the atomic weights of the different sensitive salts, and the effect of the light-waves on them, would lead to the suspicion that any alteration in the atomic weights obtained by forming a new molecule might alter that part of the spectrum which had a maximum effect. This has been practically proved by Vogel, of the Berlin Industrial Museum, Waterhouse, and others, who added aniline and some other dyes to silver bromide. These additions certainly alter the place of maximum sensibility, see fig. 96, but the writer has not been able to ascertain that, with this change, a corresponding lowering of the limit of sensibility has taken place, unless a double silver compound be formed. It has been assumed by Vogel that, because certain dyes absorb certain rays, therefore a sensitive film which is stained with such dyes should be more sensitive to that part of the spectrum in which the absorbed rays lie, than it would be were a sensitive film left unstained. If we admitted this, we must also admit that the periods of oscillation of, and the

paths described by, the sensitive molecules must be altered. This seems unlikely to be the case unless the molecules are altered in weight by the dye; in which case we should have a combination between the dye and the molecule. In some cases this may occur, and probably does; for Vogel notes that, in order to secure the alteration in the place of maximum sensitiveness, it was necessary to have some free silver nitrate left in the silver before applying the dye. An examination of the dyes he employed to obtain the effects he describes, shows that they are capable of forming an unstable compound with silver, and this organic silver salt probably combines with the silver haloid, weighting the molecule as already suggested. It is somewhat remarkable that the dyes principally effective are fluorescent, and the effect of fluorescence might be to lower the limit of sensitiveness. The writer has further found that the addition of certain resins, albumen, and other organic bodies, when combined with silver, tend to lower the limit of the impressible spectrum, and the place of maximum sensibility; so much so, indeed, that it is possible to obtain an unreversed im-

FIG. 97.



pression of the thermal spectrum. The accompanying figure gives an idea of this. A beam of light was allowed to pass through flashed ruby glass, and the spectrum was then thrown on a resinised plate in the ordinary manner. A being the limit of the visible spectrum, it will be seen how much lower the photograph extends.

In repeating the experiment of adding[1] organic matter to silver bromide, Vogel of Potsdam obtained a reversed image of the thermal spectrum without any preliminary exposure. This might be accounted for by the fact that

[1] Poggendorff, 1877.

organic matter becomes oxidized in the least refracted rays; and unless it be minute in quantity and consequently in close contact with the silver salt, it would not have the power, by its oxidation, of reducing even a small portion of the latter to the metallic state, which could act as a nucleus for development. When the quantity of organic matter is large and not in close contact with a silver salt, the organic matter when oxidized probably prevents the access of the developer to the sensitive film protected by it, and consequently the parts which are less protected by the unoxidized matter are reduced first, and thus determine the position of the further reduction. The above might also explain the action of dyes on the sensitive film, particularly when they are readily oxidizable.

It also must not be forgotten that the light transmitted through a film containing a compound in a fine state of division, may be very different to the light that the compound itself will allow to be transmitted. In the one case we may have the effect due to particular scattering, in the other we probably have the colour due to the substance itself. Thus silver bromide, when fused, is a transparent body of an orange colour; in an emulsion it may be so formed as to transmit either orange and red rays to the exclusion of the blue, or by different manipulation may be made to cut off much of the former, and transmit the whole of the blue and the violet rays.

The spectra produced upon other metallic compounds than those of silver have been studied by Herschel and others, and the student is recommended to consult Hunt's 'Researches on Light' for the particulars. The salts of iron are especially worthy of attention, some of these being sensitive to the least refrangible portion of the spectrum.

CHAPTER XXXV.

Solar, Stellar, and Metallic Spectra.

In regard to the examination of spectra, photography is playing a most important part, and we cannot do better than refer to the work first instigated by Lockyer, and now being carried out by himself, H. C. Vogel of Potsdam, Roscoe, and others. This is a preparation of a map of the solar spectrum, in which, as far as possible, every dark line is referred to the absorption due to some metallic or other vapour existing in the solar photosphere or the earth's atmosphere. Though Fraunhofer and others have already produced similar maps from ocular measurements, yet it was felt that, if photography could be enlisted into the service as a registrar, greater accuracy would be obtained and the ultra-violet portion could also be mapped. In order to carry into effect this project, Lockyer has fitted up a spectroscope with the necessary photographic apparatus as sketched in the figure. A is a vertical slit, whose exterior face is covered by a plate, capable of moving horizontally, in which two or more apertures are cut *en échelon*, the top of the lower one being in accurate continuation of the bottom of the upper one, and so on. When the top aperture of the movable plate is in front of the slit, only the top part of the slit is uncovered, and when the bottom aperture is in front of the slit the bottom part of the slit is uncovered. At B is a rack and pinion, which is used to adjust the distance of the slit from the collimating lens, inserted at the other extremity of the tube C. At D is a train of prisms (the number in which can be altered at pleasure), set to the angle of minimum deviation for the mean of the rays which it may be desirable to examine. E is a camera, some 6 feet long, furnished with a lens of that focus, and the usual means of focussing. At F is inserted the dark slide, capable of contain-

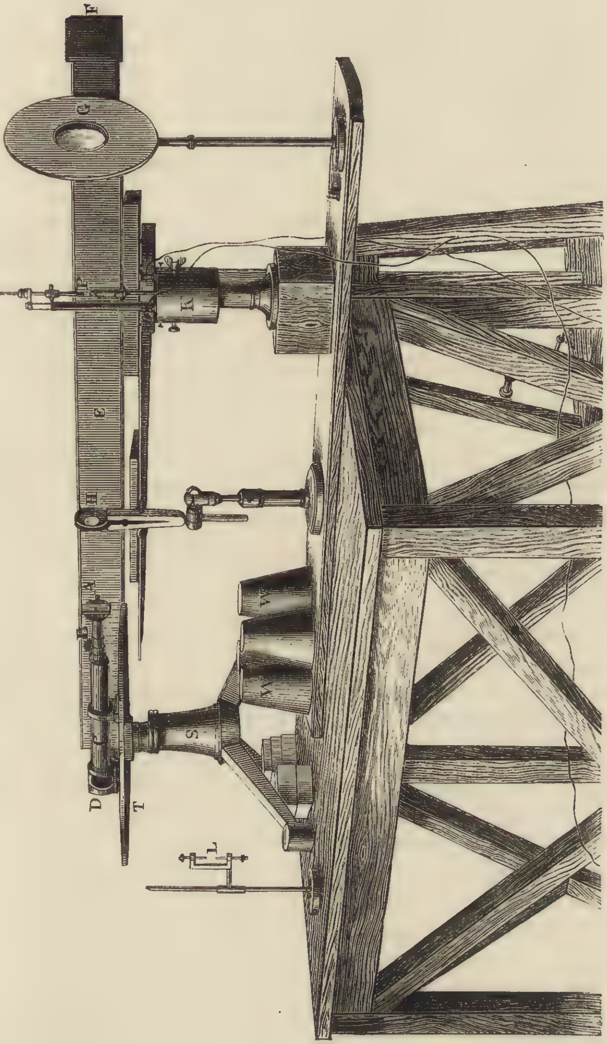


FIG 98.

ing a plate 6 × 2 inches. The spectroscope and camera are rigidly connected one with another, the prisms and collimator, C, being fastened to an iron plate, T, supported on a solid pillar, S. This completes the photo-spectroscopic arrangement. In order to compare the spectrum of a metal with that of the sun, Lockyer adopted the arrangement shown. K is an electric lamp, between the points of which the metal to be examined is volatilised by means of the electric current passing between them. The points are so placed that the interval between them lies in a continuation of the axis of the collimator C. At H is a small lens, the distance between A, H, and P being so arranged that A and P are conjugate foci of H. In some cases the place of the lamp is occupied by a Ruhmkorff coil, and the metal volatilised by the heat of the spark. G is another condensing lens on to which the solar rays are thrown by means of a heliostat, and placed at such a distance from A that its principal focus—the focus for parallel rays—is at P. By this arrangement the lens H will throw a perfect image either of the sun, or of the electric arc, on A.

Fig. 99 is a different view of the apparatus as used by Lockyer, giving an idea of the arrangement of the prisms and heliostat.

When the portion of the solar spectrum required has been accurately focussed on the plane to be occupied by the sensitive plate at F, fig. 98, the top half of the slit is uncovered, the metal to be examined brought between the carbon points, P, and the current caused to pass between them. The spectrum of the volatilised metal falls on the sensitive plate, and impresses itself in from half a minute to half an hour, the time varying according to the portion of the spectrum worked with. When sufficient exposure has been given, the carbon points of the electric lamp are separated, the bottom half of the slit uncovered (the top half being at the same time of necessity shielded from the light), and an image of the sun allowed to fall on it. As everything remains

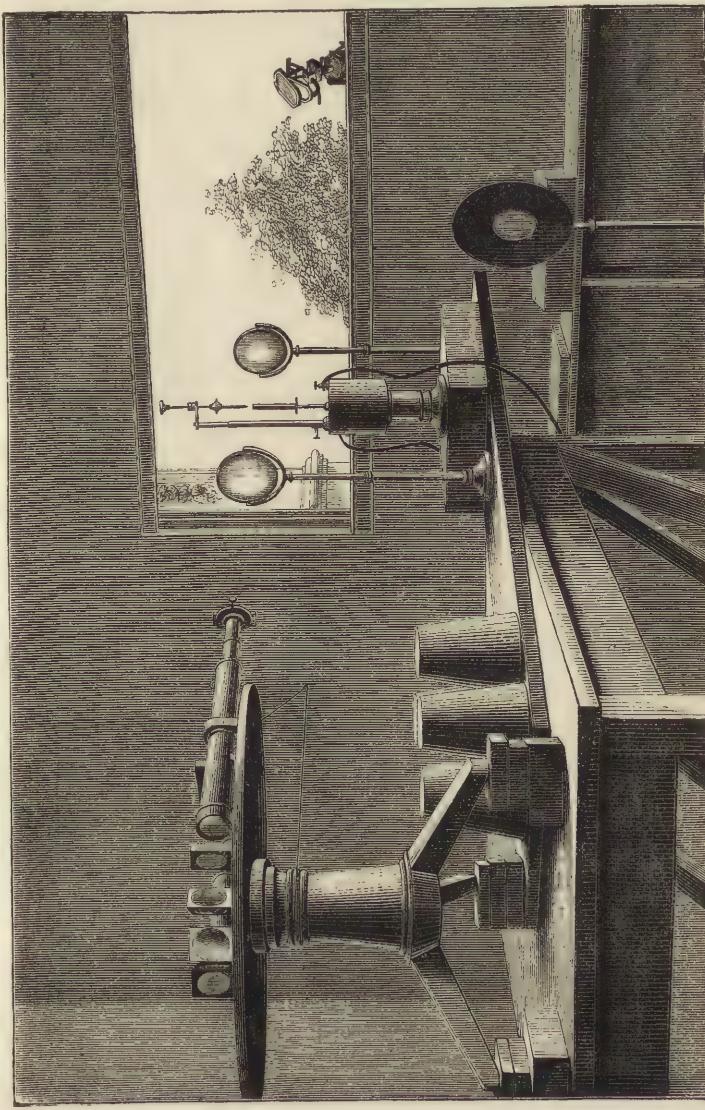


Fig. 99.

in the same position, excepting the part of the slit left open, the corresponding portion of the solar spectrum falls on the sensitive plate, but in this case immediately above that of the metal. After development the coincidence on the negative of opaque lines which are due to the bright lines of the metallic spectrum, with the transparent lines due to the absorption caused by the same vapour in the solar photosphere, can be at once determined, the one being in continuation of the other. It is not necessary to enter into the details of the results obtained from this method of observation; it is sufficient to say that hitherto metals which were supposed to be quite free from all impurity have been found to be contaminated with other metals. For a detailed account of these researches the student is referred to the 'Proceedings of the Royal Society' and 'Nature' for the last four years. It will be seen that it is quite possible to compare the solar spectrum with two metals by increasing the number of apertures *en échelon* in the sliding plate to three, if the solar spectrum be taken with the middle of the slit. Two examples of the photographs obtained by Lockyer are annexed, fig. 100. The first shows the coincidence of some of the bright lines (near H) of the spectrum of iron, with the absorption lines in the solar spectrum, and the second shows a similar comparison between calcium, aluminum, and the sun.

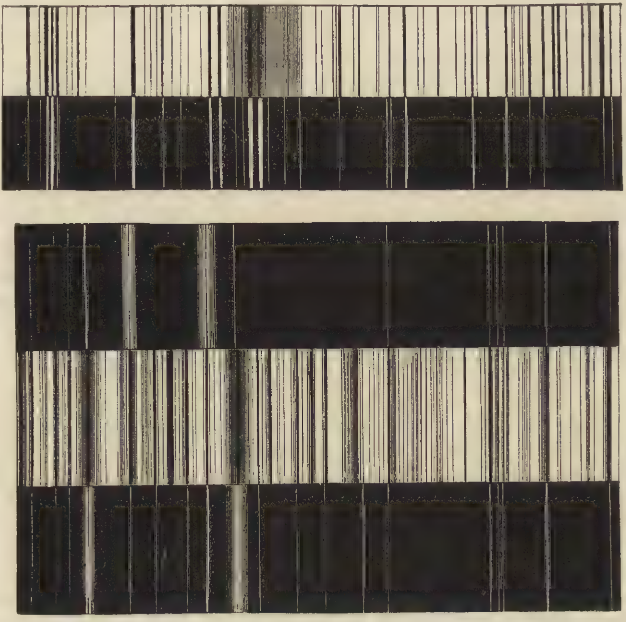
The distances between the Fraunhofer lines are measured by a micrometer, and are then mapped to a scale of wave-lengths. The wave-lengths of certain lines have been definitely determined by Cornu and others, and the measured distances of the lines are interpolated between these, and the lines due to the different metallic vapours referred to this normal spectrum.

From the photographs so obtained Lockyer has been able to obtain other important results, and is able to estimate quantitatively the different proportions of metals existing in

an alloy, by observing the disappearance of some lines from a metallic vapour spectrum, and the retention of others.

More recently Lockyer has been working with a diffraction grating of over 17,000 lines ruled on a linear inch. By employing the spectrum of the third order produced by it, he has obtained the wave-lengths in definite measure, which

FIG. 100.



he only secured previously by interpolation. It should be noted that the earliest published photograph of a diffraction spectrum, at all events of any scientific value, was due to Dr. H. Draper. He first published it in England in the 'Phil. Mag.' for Dec. 1873. The lines are not absolutely defined, but still sufficiently so to be of value.

A more recent application of photography to the spectroscope is to the securing records of star spectra.

In 1874, the younger Draper of New York commenced photographing spectra of some of the stars of the *α* Lyræ and *α* Aquilæ group,[1] and he also directed his attention to Venus. These spectra were taken with his 28-inch reflector and his 12-inch refractor. On Dec. 14, 1876, Dr. Huggins exhibited to the Royal Society a photograph of the spectra of *α* Lyræ. This physicist's method of working is described in the 'Proceedings of the Royal Society.' Briefly it may be stated that he used an 18-inch reflecting telescope, and that the reflector caused an image of a star to fall on a slit placed in front of an Iceland spar prism, through which it passed, and finally the spectrum was focussed on a miniature sensitive plate. The image of a star is always a very small disc; hence, when the image was motionless as regards the slit, owing to accurate adjustment of the driving clock of the equatorially mounted instrument, the spectrum, as photographed, would only present a thin line, broken here and there by black dots. Huggins got over this difficulty, however, by slightly altering the instrument in declination. The image of the star now travelled along the slit, and hence caused the line of altered sensitive compounds to broaden into a band, which was more easily comparable with other spectra impressed upon the same plate. The plate with the undeveloped image was left till daylight, when a spectrum of light from the sky was impressed on the plate immediately beneath the star spectrum.

Here may be mentioned the researches by the late Dr. W. A. Miller, on the absorption spectra of different transparent solids, liquids, and gases. This work was undertaken at an early date in the history of photography, but even now the results are useful when it is desired to ascertain the best material to employ for prisms, or object-glasses, with which to photograph any particular part of the spectrum. The following are some of the results obtained by Miller.

The line B reads 84 in the scale. The line H is 100.

[1] *Nature*, Jan. 1877.

In every case the commencement of the photograph was at 96·5 on the scale, silver iodide being the sensitive salt employed.

Name of Substance	Thickness in Inches	Termination of Spectrum	Relative lengths of Spectra	Remarks
Ice	About ·5	170·5	74·0	
Diamond . .	·032	155·5	59·0	
,, . . .	·017	159·5	62·0	
Quartz . . .	·16	170·5	74·0	
Fluorspar . .	·17	170·5	74·0	
Rocksalt . . .	·75	159·5	63·0	
Silver nitrate . .	·75	106·0	9·5	Saturated solution
Iceland spar . .	·35	160·0	63·5	
Faraday's optical glass	·54	101·5	5·0	Pale yellow
Flint glass . .	·68	105·5	9·0	
Window sheet glass .	·07	112·5	16·0	
Hard Bohemian glass	·18	114·5	18·0	
Plate glass . .	·22	111·5	15·0	
Crown glass . .	·74	106·5	10·0	Greenish

The spectrum apparatus was fitted with a quartz lens and a quartz prism, hence no estimate can be formed of the extent to which it is possible to photograph the spectrum apart from the absorption due to that material.

The lower limit of the extent of the spectrum has not as yet been ascertained. In a paper read before the British Association, at Plymouth, Lord Rayleigh showed what should be the theoretical lower limit of the *prismatic* spectrum, but this is not necessarily the limit with a diffraction spectrum. In Sir John Herschel's experiments with the thermal spectrum, the apparatus described in the last chapter seems to have been employed ; and, according to the recorded results, the limit does not agree with those obtained from similar experiments carried out by Lord Rayleigh, and which apparently agree with the theory. The principle adopted by Herschel in these experiments was the drying of paper moistened with alcohol when exposed to the heat rays. A paper was coated at the back with lampblack,

brushed over in front with alcohol, and immediately exposed to the spectrum. The paper, which when moist was translucent, became opaque when the heat had caused the alcohol to evaporate, and thus the thermal region was indicated. When ferro-cyanide of potassium and ferric oxalate are brushed over paper together they do not immediately combine and form Prussian blue, but exposed to heat they pass through an intermediate stage of combination, forming a brown compound. In Lord Rayleigh's experiments paper treated by such methods gave the same limit to the prismatic spectrum, which differed from that obtained by Herschel. Further investigation is still required.

CHAPTER XXXVI.

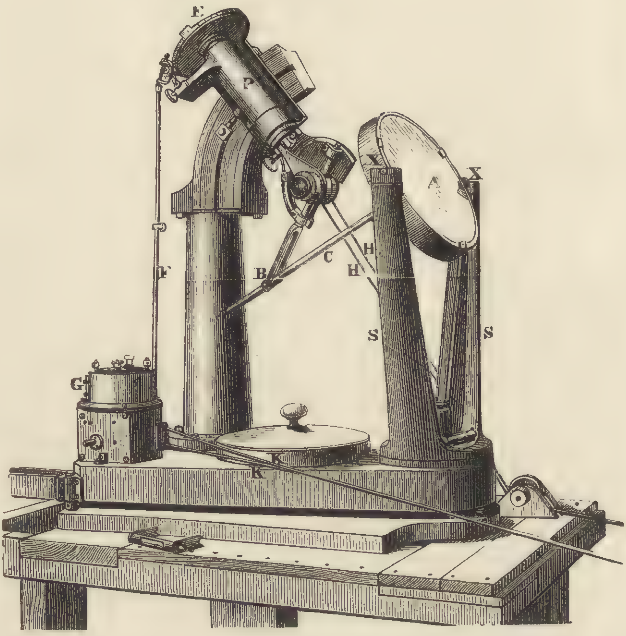
CELESTIAL PHOTOGRAPHY.

PHYSICISTS have turned photography to account in their study of the heavenly bodies, most of which, in one way or another, have been made to impress their image on sensitive plates. The student who may ta' e a landscape with the sun shining direct into the lens will soon satisfy himself that the exposure necessary to obtain a good photograph of our luminary, when unclouded, is very small, so short, indeed, that solarisation is frequently induced, though the landscape itself may be capable of proper development. With the ordinary camera and lens an image of the sun is practically useless, since a lens of short focus is only capable of giving a very small image, and one on which none of the markings which characterises his surface can be seen, even with the aid of a magnifier; and since the prime object of solar photography is to enable the surface of the sun to be studied, it is evident that other means must be adopted

in order that it may be delineated on a sufficiently large scale. An ordinary lens or object-glass gives an image of the sun of a diameter of about $\frac{1}{10}$ of an inch to a foot of its focal length. It is, therefore, evident that in order to secure a photograph of it of 4 inches (about 10 centimetres) diameter, the lens employed must have about 40 feet focal length. Now, 4 inches has been proved by experience to be about the least diameter for a solar image in which sunspots can be effectually studied. Hence, for a direct photograph taken at the principal focus of the lens, the focal length should not be less than 40 feet. Before the introduction of Foucault's siderostat a telescope would have had to be mounted equatorially, and a clock motion would probably have been necessary, since the motion of the earth, even with the short exposure necessary, would have marred the definition to a certain extent. Since siderostats have been classed amongst available instruments, the difficulty attendant on the mounting of such an enormous length of telescope has disappeared, and a lens of great length can be employed, mounted on a less heavy tube, placed in any convenient position, and supported in its length, if necessary, along the ground. A siderostat belonging to the Royal Society, made by Cooke on Foucault's model, is given in the accompanying fig. 101. Its principle is the same as that of the heliostat, already described at p. 271, and shown at fig. 95. A is a mirror, silvered on the external surface, which has been worked to a perfect plane. It is suspended on two axes, X X, working a U-piece, S S, pivoted at the base, and therefore capable of moving the mirror so as to face any given direction. P is the polar axis, set so as to point to the pole of the heavens; the inclination being regulated by a movement along an arc, affixed to the principal supporting pillar of the instrument. Attached to the polar axis is the declination circle, E, to which the ordinary movement is given by the clockwork, G, which communicates its motion by the connecting rod, F. To the lower

extremity of the polar axis is attached a movable arm, which can be clamped, so as to form any angle with it. At the bottom of this arm is a socket joint, pivoted at B, in which C, a rigid and perfectly true rod, is capable of sliding. When using the siderostat, it should be set with the polar axis in the meridian. The beam of light can then be caused to be projected in any given horizontal direction by

FIG. 101



the motion of S S, whilst its vertical direction is adjusted by the movement of the arm B. K K are cords which can turn F, and consequently E, and hence the motion of A in the horizontal plane can be adjusted without interfering with the movement of the clock. H H are cords working on the

movable arm, to which B is attached ; a vertical adjustment can therefore be given to the reflected beam.

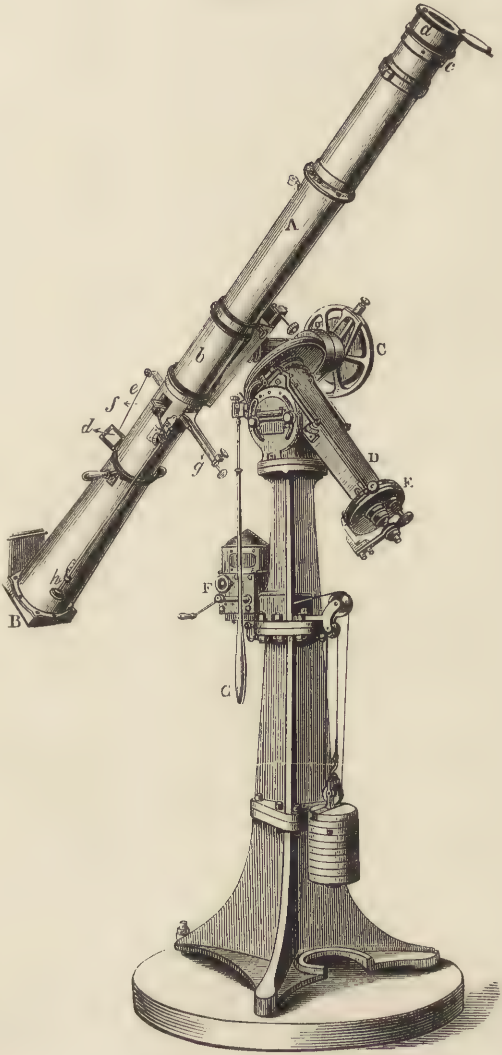
The following method can be employed for obtaining a solar image with the very long focussed lenses by the aid of the siderostat. The lens with its tube is placed in a position such that the direction of their axes cuts approximately the centre of the mirror. Since the mirror is supposed to be a perfect plane, it is manifest that an image of the sun should be formed at the principal focus of the lens, as perfect as if the axis of the lens itself were pointed to the luminary. It is needless to describe the camera, which, in fact, instead of being attached to the tube, may remain detached so long as the plane of the sensitive plate is kept accurately perpendicular to the axis of the lens, and so long as all light, except that admitted through the lens, be excluded. This is, perhaps, better than rigidly attaching it to the body of the tube, as it gives facilities for exposing the plate very close to the principal focus. It has been considered most important that such a position for the exposure should be obtained. The reason of this will be evident when it is remembered that the only means of giving the exposure is by causing an opaque screen, in which a slit is cut, to pass across the beam of light. Were such a screen passed in front of the lens, or at any part of the telescope other than the principal focus, the impression of the image might continue during the entire exposure. When the exposure, however, takes place at the principal focus of the lens, during each portion of the exposure a definite portion of the image alone is impressed. To secure good detail in the representation of the sun's surface such a method of impressing the image is necessary, since, however excellent may be the workmanship of an instrument, there is always some small tremour in the movements, and consequently a risk of an imperfection in the image. There is much to be said in favour of this method of solar photography, and something to be said against it, and it seems a

point which has yet to be decided as to whether this or the plan next to be described is likely to give the most accurate results.

The instrument which was first adopted for solar photography was one designed by De la Rue, and known as the Photo-heliograph. The accompanying figure shows the latest pattern, and is taken from one of those which was lately employed by the expeditions for observing the transit of Venus. At *a* is a lens of about 4 feet focus, having a cell on which is cut a very fine screw, so fine and accurate, indeed, that the lens can be caused to advance or recede from B by the $\frac{1}{1000}$th part of an inch by turning the cell through a portion of a turn. About *f* is the principal focus of the lens, at which point are placed cross wires or a ruled grating; the focus of which can be accurately obtained by a slow-motion screw turned by the handle, H. This moves an inner tube in which the diaphragm holding the wires is inserted. Immediately in front of *f*, and running in a pair of grooves, is the exposing screen, in which there is an adjustable opening or slit. At *g* is a spiral spring, which tends to keep the slit below the point where the image is formed, whilst at *e* is a little pulley, over which runs a thread attached to the top of the exposing diaphragm, and terminating by a loop. The preliminaries to exposure are to draw the diaphragm up to *e* by the thread, and then to place the loop over a pin (not shown in the figure); this brings the slit *above* the place where the image is formed. The exposure is given by cutting the thread; the spring, *g*, pulls the diaphragm towards it, and the slit traverses the image. The duration of exposure can be regulated between $\frac{1}{20}$th and $\frac{1}{100}$th part of a second, a margin sufficiently wide to suit the sun as seen through almost any condition of the atmosphere.

Below *f* is placed a magnifying lens, which takes the form known as 'the rapid rectilinear.' Its function is the same as that of an eye-piece in a telescope, and by altering the distance between its optical centre and the focus of the object-glass any size of image can be produced. In the

Fig. 102.



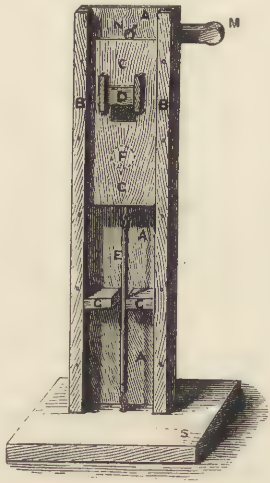
instrument under consideration the diameter of the sun's image has been fixed approximately at 4 inches, and consequently the adjustments of the secondary lens are made so that there cannot be much variation from those dimensions. B is the holder in which the slide carrying the sensitive plate is placed. Some of the means of adjustment have already been pointed out; a further one is that of the secondary magnifier, which by a slow-motion screw can be caused to recede or advance along the axis of the telescope. It will be seen that every means of securing a sharp image of the sun together with that of the cross-wires or ruled gratings is to be found in the instrument. The telescope is mounted equatorially, D being the polar axis, C and E the declination and right ascension circles, and F the clock movement. By means of G a motion can be given to the tube in right ascension, and by a corresponding handle attached to the tube (and not shown in the figure) a motion in declination. The greatest danger to the accuracy of this instrument is distortion, through the multiplication of lenses, and the risk that exists of these not being properly centred. When attention has been paid to this, as it has been by the eminent optician who has constructed them, they leave little to be desired.

It is not probable that the student will be in possession of either of the two instruments which have been described. A very fair substitute for them can, however, be made by anyone who possesses a telescope of fair defining power, a doublet lens of say 20 to 25 centimetres equivalent focus, and a perfectly plane mirror, silvered on the exterior surface and mounted on a stand. The eye-piece should be removed from the telescope, and the tube of the latter mounted on a cradle of such a height that the axis of a photographic lens, when in the camera, coincides with the axis of the object-glass. For this purpose it is advisable that the distance of the lens from the ground-glass screen of the camera should be capable of adjustment by a fine rack and pinion motion

governing the lens itself. Supposing it be required to secure a photograph of the sun, having a diameter of about 20 centimetres, the lens must be roughly placed at the distance which will give that size, and afterwards any small alteration in focus made by moving the lens in the draw-tube, or by using the adjustment at the back of the camera. As before stated, the former method is the better, as then the camera may be fixed rigidly in position, and nothing altered excepting the lens itself. In the interval which there will be between the lens and the eye end of the telescope will be the principal focus of the telescope, and at that point may be placed an apparatus for giving the necessary exposure. This may be entirely separate from the apparatus, and may be conveniently made by causing a diaphragm with slit to drop in front of the instrument by means of a falling weight or a spring. One can be constructed of cardboard and wood, which will answer every purpose. First, a board, A, some $\frac{1}{2}$ centimetre thick, was placed on a stand, S. On each side of A were fixed a couple of small shaped battens, which formed a groove sufficiently large for a stout Bristol board to slide freely in. At F was an opening (shown by the dotted circle) which was at the principal focus of the telescope. The cardboard, C C, was cut with an opening, E, which could be widened or narrowed, as might be required, by a small card, D, likewise running in grooves placed over it. Attached by a loop to the bottom of the card and to the stand is an India-rubber spring E. The card C is held in position by a small pin, N, covering this A, and worked by a trigger, M. To expose, the card is first brought into the position shown, and the trigger pressed. The slit passes over the opening D, and the movement is finished when the card comes in contact with G G, two projecting pieces, as shown. If the card be blackened, and a black cloth be lightly thrown over this apparatus, the end of the telescope, and the camera, there is no danger of any extraneous light affecting the plate, provided the latter be

capped immediately before and immediately after exposure. The plane mirror, of course, must be adjusted so that the beam of light from its centre falls along the axis of the object glass.

Fig. 103.



Some of the best solar photographs that the writer has seen were taken by an uncorrected lens of long focus; and it certainly is as good to have one totally uncorrected as one only approximately achromatic, if a collodion be used in which there is very little bromide. The reason of this will be apparent when it is considered where the maximum chemical activity of light of the spectrum is situated in regard to silver iodide. When sufficiently short exposure is given to the plate, only that particular part of the spectrum is effective in forming the image. Now the foci of the different rays of the spectrum vary enormously when an uncorrected lens of long focus is employed; if therefore a plate be exposed at that point where the rays of maximum effect are

brought to a focus, it is manifest that a perfectly sharp image can be secured. It is perfectly feasible by this expedient to secure photographs of a fair size without having to resort to a magnifying arrangement, and the expense of fitting up such an apparatus would be, comparatively speaking, small.

The latest development of solar photography is due to Janssen. He employs a revolving plate, and causes exposure to be made automatically on different portions of it at certain fixed intervals. By this means he is enabled to secure a series of pictures with the greatest comfort, and can examine any changes that may occur in every few hours on the sun's surface. There seems to be a promise of good results being derived from this procedure, and it remains to be seen if new inferences may not be drawn by the comparison of observations simultaneously made at different parts of the earth.

The next question that arises is as to the process of photography which is to be adopted. This depends entirely on the purpose for which the sun-picture is to be made. To study the sun's *surface*, unquestionably the process should be employed which will give the greatest roundness[1] to the picture, and this is to be found in the wet process, using the pyrogallic acid developer, with a nearly neutral bath, as given at p. 89. The following formulæ for dry plates are used by Janssen, and the pictures, 30 centimetres in diameter, leave nothing to be desired. The collodion is made as follows :—

Pyroxyline	8 grammes
Alcohol	400 cc.
Ether	600 cc.
Ammonium iodide	4 grammes
Cadmium iodide	3 grammes
Potassium iodide	2 grammes
Ammonium bromide	1 gramme
Cadmium bromide	1 gramme

[1] There is a variation in the intensity of light at the limb and at the centre of the sun's disc: that of the latter is between four and six times that of the former.

The pyroxyline is of a peculiar character, being excessively soluble, and is probably prepared at a high temperature. For ordinary samples the quantity might well be nearly doubled. The plate is sensitised in any ordinary bath, and a solution of tannin of about 1 per cent. is floated over the plate after it has been carefully freed from all free silver nitrate. The development is conducted by plain pyrogallic acid till a faint image is brought out, after which intensity is given by the application of pyrogallic acid, acetic acid, and silver nitrate. Janssen states that alkaline development caused a loss of roundness and relief in the image, and the same may certainly be said of development of a wet plate by iron solution *unless that solution be very weak.* The reason of this is that, in order to cause the smallest differences in the chemical activity of light to be apparent, the reduction of silver should take place *very slowly* (read p. 65). Plain pyrogallic acid is a much less energetic reducer than alkaline pyrogallate or than ferrous sulphate ; hence the roundness of an image is lost by employing the two latter.

When it is necessary that the limb of the sun should be exceedingly sharp and defined, as it was in photographing the transit of Venus across the sun's disc, so that measurements of the distance of the planet's limb from the solar limb might be taken, the wet method employing the iron developer is effective, or a dry plate process with strong alkaline development will be efficacious. For the English expedition sent out during the last transit the process given at p. 109 was employed, and from the measurements from different plates proving fairly accordant it is to be supposed that it is suitable for the purpose.

It seems that in the earliest days of the discovery of photography by Daguerre impressions of the solar image were made, and it would require a somewhat long list to record the names of those who have successfully adapted the art to astronomical purposes. For the registration of the phenomena connected with the total eclipses of the sun the

same difficulties as to names of the workers would arise. The first recorded endeavour to employ photography for this work dates back to 1851, when Berkowsky obtained a daguerreotype of the solar prominences during the total eclipse. From that date nearly every total solar eclipse, the observation of which was possible to European observers, has been studied by its aid, and has tended to the solution of some of the problems which arose concerning the solar physics. In 1860 the first regularly planned attack on the problem by means of photography was made by De la Rue and Secchi, and in subsequent eclipses it has been continued. In 1875, in addition to photographing the corona, attempts were made to photograph its spectrum. To what extent success was obtained in this is not yet officially known, as the report of the observers has not as yet been published.

As regards photographing the corona the general opinion seems to be that it is better to employ an ordinary photographic lens of a focal length of some 80 centimetres with the camera mounted equatorially, than to employ the ordinary telescopic objective. The coronal light during the eclipse is faint, and in order to get full effect it is necessary that the ratio of the aperture to the focal length should be as great as possible. It is for this reason that success with a photoheliograph, where the image is enlarged, is more than problematical, unless a process which is very much more sensitive than any of those at present known can be brought into operation.

There is no great speciality in the methods of manipulation which need be referred to, discipline, regular drill, and absolute cleanliness being the chief essentials when the atmospheric conditions render success possible.

Lunar photography has occupied the attention of various physicists from time to time, and when Daguerre's process was first enunciated, Arago proposed that the lunar surface should be studied by means of the photographically produced images. In 1840, Dr. Draper succeeded in im-

pressing a daguerreotype plate with a lunar image, by the aid of a 5-inch telescope. The earliest lunar photographs, however, shown in England were due to Professor Bond, of the United States. These he exhibited at the Great Exhibition of 1851. Dancer, the optician, of Manchester, was, perhaps, the first Englishman who secured lunar images, but they were of small size. After these might be mentioned many names, but it is unnecessary to refer to any before that of Crookes, who took the next step in the matter. The instrument that Crookes employed was an 8-inch refractor, belonging to the Liverpool Observatory, which had a focal length of about $12\frac{1}{2}$ feet. The diameter of the moon was therefore about 5 centimetres. Crookes affixed a small camera to the telescope and focussed the actinic rays by trial, there being found a great deviation between their focus and that of the visual rays. The motion of the moon not being capable of being followed in the telescope by means of the ordinary equatorial arrangement driven by clock-work, the necessary accuracy was obtained by mechanically following it by means of the slow-motion screws attached to the declination and right ascension circles. The cross wires in the finder were kept on one point of the image of the lunar surface, a high magnifying power being used in the eye-piece. Crookes found that with different telescopes the necessary exposure varied between 4 seconds and 6 minutes.

In 1852, De la Rue began experimenting in lunar photography. He employed a reflector of some 10 feet focal length, and about 13 inches diameter. An abstract of a paper read before the British Association appeared in the 'British Journal of Photography.' In it is given a very complete account of the methods he adopted.

In the first part of the paper De la Rue points out that if the image of a bright star is allowed to traverse a photographic plate, the result is not, as one would expect, a straight line, but one which is broken up and disturbed, and which

consists of an immense number of points crowded together in some parts, and scattered in others. These disturbances being due to our atmosphere, it follows that if the telescope be made to follow the motion of a heavenly body, an exposure other than instantaneous must, to a greater or less extent, render every point of it a confused disc, and that, therefore, a photographic image will never be so perfect as the optical image given by the same telescope until instantaneity be secured.

'Notwithstanding, however, the disadvantages under which a photographer labours, I have obtained pictures of celestial objects showing details which occupy a space less than two seconds in each dimension. I might, I think, say even one second. Now 1 second = $\frac{1}{200}$ of an inch on the collodion plate, a second on the lunar surface, at the moon's mean distance being about 1 mile. The lunar picture in the focus of my telescope is about $1\frac{1}{10}$ inch diameter, but this varies of course with the distance of our satellite from the earth.' . . . .

De la Rue then stated that he considered a magnifying arrangement attached to the telescope as impracticable to secure good pictures, owing to the increase of exposure that would be necessary, and the consequent defects due to atmospheric disturbances. He considered that the enlargement ought to take place after the negative is taken.

He then describes the adjustment of the motion of his telescope to the lunar motion, which he effected by altering the length of a conical pendulum or friction governor, which altered the time of its rotation (or double beat). He proposed to effect the same alteration by another plan, which he subsequently adopted.

De la Rue at first obtained his lunar pictures in his 13-inch reflector, by placing the sensitised plate at the side of the tube opposite the diagonal reflector, the light being thus twice reflected. Subsequently he obtained pictures

directly at the focus of the mirror, which did not give him that increased rapidity of exposure which he had conjectured would result. He states: 'I am inclined to infer that Steinheil's result, as to the loss by reflection of the luminous ray, does not hold good as regards the actinic ray.'

He next compares the advantages of the reflector over the refractor, the principal one being that the foci of the actinic and visual rays are coincident.

'The time occupied in taking lunar pictures varies considerably. It depends on the sensitiveness of the collodion, on the altitude of the moon, and the phase. I have recently produced an instantaneous picture of the full moon, and usually get strong pictures of the full moon in from 2 to 5 seconds. . . . . The moon, as a crescent, under like circumstances, would require about 20 to 30 seconds in order to obtain a picture of all the parts visible at the dark limb.'

'Portraits of the moon equally bright optically, are by no means equally bright chemically; hence the light and shade in the photograph do not correspond with the light and shade in the picture; and hence the photograph frequently renders visible details which escape optically. Those portions of the moon near the dark limb are copied photographically with great difficulty, and it frequently required an exposure 5 or 6 times as long to bring out those portions illuminated by a very oblique ray, as others apparently not more bright when more favourably illuminated.'

In the practical instruction for the photography, De la Rue lays down that the silver bath must be as nearly neutral as possible, that cadmium iodide is the best iodiser to use with the collodion, and that the pyrogallic acid developer should be employed. For lunar photographs there can be no doubt that if they are required to be enlarged, iron development should not be attempted, since the deposit becomes too granular; but we are inclined to think that the

rapid bromide emulsion plates developed by the alkaline method will furnish pictures which are equal to those produced by the wet method as described above, and certainly give a great decrease in exposure.

Mr. Rutherfurd at a later date having tried an $11\frac{1}{2}$-inch refractor of the ordinary type, and also a 13-inch reflector, finally constructed a refracting telescope in which correction was made only for the chemical rays, and with this instrument he has produced some of the finest pictures of the moon which have ever been taken. With the great Melbourne reflector, however, photographs which are nearly perfection have been obtained, and there seems even yet to be a balance of opinion in favour of the reflector as against the refractor for this kind of work. Undoubtedly, where absolute coincidence of foci of all rays can be secured, all other conditions being the same, the best photographs ought to be obtained. In lunar photography an unfavourable condition of the atmosphere is undoubtedly the greatest difficulty to be encountered. In a climate like England the air is rarely steady enough for the purpose. In countries which are more favourably situated as regards hygrometric conditions the difficulty is much reduced. In 1874-5, whilst the writer was in Egypt, Colonel A. Campbell and himself had an opportunity of taking some lunar photographs with a refracting telescope of 7-inch aperture belonging to Mr. W. Spottiswoode. On the nights that the experiments were made really excellent negatives were obtained, which bore enlarging to 12-inch diameter. The apparatus employed was extemporised, and therefore of a rather rude description, but quite sufficiently true to give an idea of the excellent pictures that might be taken in such a climate with the appliances usually adopted for such work.

Photography as applied to delineating the planets or stars has not as yet yielded much that is satisfactory. Of the former Jupiter and Saturn, Venus and Mars, have all been photographed, but without increasing the knowledge that

already exists regarding them. Photographing the stars is more a feat of photography than of practical utility in the present state of our knowledge, though at some future time it may be possible to map the heavens more thoroughly by its aid than has at present been done.

Rutherfurd has been the most successful in this branch, applying it to the measurement of the distances of double stars, and it may not be uninteresting to point out the method which he adopted. With the refractor already referred to, the proper chemical focus having been ascertained, the stars which it is desired to photograph are brought into the field and an exposure given for the time that may be considered necessary ; stars of the 9th magnitude requiring an exposure of 8 minutes. The telescope, of course, must be made to follow very accurately the apparent motion of the star, and perhaps it is the uncertainty of this that is likely to cause the greatest difficulty in the whole of the operations. After an exposure is given, the clock is put out of gear for some seconds; the axis of the telescope now occupies a slightly different position in regard to the stars in the field of view, and a fresh exposure of the plate is given. On development a double series of stars appears, an artifice adopted to prevent any mistake being made between the image of a star and an accidental blemish on the film. Finally, to determine the true position of the stars as regards the north point, a bright star is brought on to the left edge of the plate and the telescope allowed to remain stationary. The track made by the star determines the true east and west points for the picture.

CHAPTER XXXVII.

PHOTOGRAPHY WITH THE MICROSCOPE.

Photography from a very early period of its existence has been utilised for securing accurate drawings in monochrome of what the eye can see in the microscope. This branch of the art is excessively fascinating, and can be worked in any leisure moments, either by day or night, when the enlargement is limited to say 50 diameters; but in order to secure images of greater dimensions it is always advisable to employ sun-light. The apparatus required is not very extensive. An ordinary microscope with say $\frac{1}{4}$-inch and 1-inch objectives and an A eye-piece is all that is necessary as far as the instrument itself is concerned. If the objects to be photographed are mounted on a slide, and not merely placed in a cell for examination, any ordinary camera may be attached to the microscope, as the tube can then be brought into a horizontal position. It has often been recommended to employ a camera as much as 6 feet in length, in order to secure great increase in the size of the object, but in the writer's experience it is unwise to go beyond 18 inches, a length just sufficient to enable the operator to grasp the slow-motion focussing-screw, whilst his eye can be directed to the focussing-screen. When the longer camera is employed, the operation of focussing has to be conducted by an assistant, and, however intelligent the latter may be, it will always be found that greater accuracy will be obtained by the operator's own hand, for it must be recollected that the difference of $\frac{1}{1000}$ of an inch in length of focus may determine whether the definition is good or bad.

The camera and the microscope should not be attached rigidly to one another. It is far better that each should be

free to move independently, though care should be taken, when an accurate focus is obtained, that each shall occupy a perfectly unalterable position during exposure. Perhaps the most simple way of attaining this object is to substitute for the ordinary photographic lens used with the camera a short brass tube, which screws into the flange. A piece of velvet should then be formed into a cylindrical bag, open at both ends, and a little longer than the brass tube above referred to. If each opening of the bag is provided with an elastic band, a perfectly light-tight junction between the tube and the body of the microscope may be made.

Some operators prefer to use the eye-piece as a magnifier; it seems better, however, simply to employ the objective. If the objective only be used, it is wise to unscrew the tube of the microscope, in order to secure a larger field, which otherwise the diameter of the tube would limit. It must not be inferred that the use of the eye-piece as a magnifier will cause indifferent pictures in every case. In the instrument used by the writer the definition given by it was certainly bad.

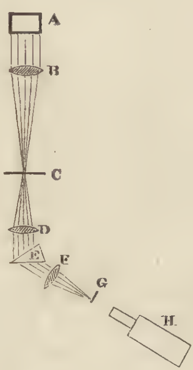
The student is recommended to commence with a comparatively low-power objective. The 1-inch will be suitable in every way; and whenever he has obtained mastery over the manipulations with it, he may venture on the $\frac{1}{4}$ or $\frac{1}{8}$-inch. A higher power than these can seldom be recommended; probably the $\frac{1}{4}$-inch is the highest power which can be worked with ease. The tube of the microscope should be placed in an accurately horizontal position, as should also the camera; and care should be taken that the axis of the tube fixed in the latter should be in the exact continuation of the axis of the lens. This can only be effected by very careful arrangements. As a rule it will be found that when the body of the microscope is in a horizontal position the friction on the axis on which it turns is sufficient to cause it to remain in the position in which it is placed; if not, obvious precautions must be taken to

prevent any movement between the time of focussing and exposing the plate. Supposing that sunlight is to be employed for the purpose of illuminating the object, the next operation is to throw the image of the sun by a condenser on the object, in such a manner that the axis of the condenser and that of the objective may be in a line with one another. This may readily be ascertained by noticing the illumination when no object intervenes between the rays emerging from the condenser. It is advisable, first of all, however, to place the heliostat (the one described at p. 271 answers the purpose) in position. This can be done with sufficient accuracy by rough observation with the eye, and noting that the centre of the mirror is about the same height, and in the same horizontal line as the tube of the microscope. The condenser is then brought into the reflected rays, and an image of the sun brought to a focus on the object. In some cases the heat rays have to be cut off, otherwise injury to it ensues. A glass cell with parallel sides containing a solution of alum is found to subdue the heat sufficiently when placed in the path of the beam. The focussing is now proceeded with, and is best performed by removing the ordinary ground glass, and substituting for it a plate of ordinary patent plate, viewing the image by a focussing glass, as described in photo-spectroscopy, page 269. The portion of the object to be photographed should be brought into the centre of the field, and when nearly in position the slide should be clipped on to the stage by a couple of wire springs, and the adjustment effected in the usual manner. The absolute focussing should next be taken in hand. A rough approximation is first obtained by the rack and pinion motion, and the final focus obtained by the slow motion screw, which is attached to every good microscope. When viewing the image through the focussing glass it will be found that in no position is the object quite free from colour. In one focus it will appear sharply defined, though

surrounded by a red band, whilst the definition will appear equally good when in a different focus, when surrounded by a blue halo. These colours are due to a want of achromatism in the objective, and the *former* position should be chosen to obtain a sharp photograph; for since the blue rays are as a rule the most active in causing the photographic image to be formed, it is evident, if the latter focus, which is most accurate for the red rays, be chosen, the resulting picture will be blurred.

Monochromatic Light.—The fact that coloured fringes are sure to border the image shows at once that the objective is not properly corrected, and there would evidently be an advantage were it possible to work with monochromatic light. This can be accomplished in the following manner, and it is believed the arrangement is somewhat novel: certainly the photographs obtained by this plan are far superior to any obtained by the writer in which white light is employed.

Fig. 104.



A is the heliostat, throwing the sunlight on B, a condenser of 4 feet focus. Such gives an image of the sun on a slit about a quarter of an inch in width. The lens D, of a focus of about 12 inches, takes the place of the collimating lens, throwing parallel rays on a prism E. This may be a hollow prism filled with carbon disulphide, such as is used for the exhibition of spectra with the electric light. The rays of light after being refracted are received by a lens F. This may be of varying length, according to the power of the objective employed. Should it be a long focussed objective and a correspondingly large object which has to be photographed, the focal length of F should be about 18 inches. With a $\frac{1}{4}$-inch a 9-inch focal

length will be found sufficiently powerful. The reason of this difference is that the spectrum is thrown on the slide containing the object, and the part of it to be photographed should be illuminated with rays of the same colour, and for this reason also the slit should be widely opened. The light, of course, will not be absolutely pure, but it will be sufficiently so to prevent any appreciable difference in the colour of the rays transmitted through the objective. The same object may be obtained by throwing the direct rays of the sun on the prism and then collecting them by means of condensers of variable focal lengths, the length being determined as given above. The spectrum thus produced is focussed on the plate as before. There is a slight danger in this method of getting the spectrum rather too impure. If either plan be adopted, any portion of the spectrum may be made to illuminate the object, by slightly shifting the lens F in a direction at right angles to the axis of the microscope but care should be taken that as far as possible the rays are in the direction of the axis itself. To fit up an apparatus as above described takes a little ingenuity, but after a trial or two it is easily accomplished.

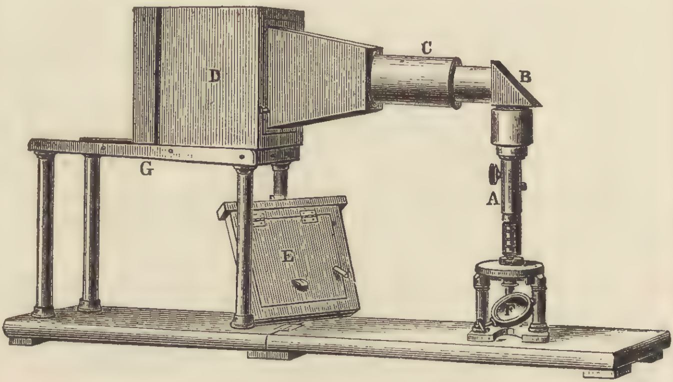
The best rays to employ are the indigo rays immediately following the blue. It is a mistake to employ the violet, as the exposure then becomes unnecessarily long. It may be noted that by using a monochromatic light for eye observations the definition is wonderfully improved. Many details which are altogether wanting with white light are brought into view by it. It may be found that for studying objects of different colours different rays are the most suitable for illuminating them.

The photographic delineation of opaque objects is much more difficult to accomplish than that of those which can be examined by transmitted light. The difficulties will be found to increase rapidly if any endeavour be made to use a higher power than a $\frac{1}{4}$-inch. The same arrangement as that indicated may be employed, causing, however, the

rays to fall on the object. This gives a very feeble illumination, and with great magnifying power the difficulty of focussing is excessive. When once a focus is obtained all difficulty vanishes, and by the use of dry plates any amount of exposure may be given without any deterioration of the image.

The annexed figure shows an arrangement by which a microscope may be employed in its ordinary vertical position. The instrument was in the Loan Collection of Scientific

FIG. 105.



Instruments at South Kensington, and is of German make. The form of the camera might advantageously be altered to a bellows shape. A is the microscope; B a right-angled prism reflecting the rays of light which pass through the objective into C, a brass tube fixed to the camera D. The length of the camera is supported by two iron rails G. It will be noticed that the same method of illumination can be applied in this position of the microscope as when it is used horizontally, for the rays of light can be reflected by the mirror F.

Hitherto we have only supposed the student to be working with sunlight, but as may already have been inferred, artificial light may be employed. The great desideratum with the latter is that it should be steady, and should proceed as nearly as possible from a point. The light from a magnesium lamp has been recommended, but in the writer's experience it is most unsatisfactory. The electric light is good, but is somewhat difficult to manage, though, owing to the intensity of the illumination, the time necessary to keep the points in proper adjustment is not very great. The lime-light, perhaps, possesses the greatest advantage over all lights, since it is so perfectly steady. With an oxyhydrogen source of illumination an object can be well enlarged up to 50 diameters, though with the spectrum apparatus the illumination is very feeble.

As already stated, the wet or dry processes may be employed in photography with the microscope. The former is perhaps the most satisfactory, if the exposure only reaches to reasonable limits. There is a danger of the sharpness of the image being blurred by irradiation, and the writer has found that by using the Warnerke tissue this has been entirely overcome. Another great obstacle to the attainment of good pictures consists in the diffraction images of parts of the object. This, of course, is dependent on the relative sizes of the object and of the aperture of the objective.[1] It is partly for this reason that the $\frac{1}{4}$-inch gives superior photographs to the $\frac{1}{8}$. This defect may, however, be almost totally remedied by throwing the light from a source of illumination on to a translucent screen, and making this surface the source of illumination of the object. The exposure is of necessity much prolonged by adopting this plan.

[1] See Airy's 'Undulatory Theory of Optics.' Macmillan and Co.

CHAPTER XXXVIII.

MISCELLANEOUS APPLICATIONS OF PHOTOGRAPHY.

IN a short work, limited as to size, it would be naturally impossible to give even an outline of all the many and varied applications to which photography can be and has been applied. In this chapter it is proposed to give a few of them, more for the sake of informing the student what has been done, than for teaching him the practical method of working them. The method of securing the automatic registration of barometers, thermometers, and magnetometers should command our attention first. It will be necessary to divide these into two classes which require different treatment. A mercurial thermometer may be taken as the representative of the first class.

Supposing we have a darkened chamber, in the side of which is a slit of just sufficient dimensions to allow the bore of the capillary tube to fill it, and that light can only have access to that chamber after passing through that slit when so closed, it is manifest that if a strip of sensitive paper be caused to pass gradually behind such a thermometer tube the different height of the mercury will be registered, owing to the opacity of that fluid to light. If the supply of paper be properly regulated it is also manifest that the height of the mercury at any particular instant will be known. Since daylight is not always available, resort must be had to artificial light to impress the sensitive paper, and a suitable process of development employed.

Such a method exists for registering the movements of this class of instruments, the details of apparatus and manipulation being altered to suit each individual case. There are, however, other instruments to which such would be totally inapplicable. As an example, we may take the magnetometer. The oscillations of the suspended magnet as used for measuring the horizontal or vertical components

of the earth's magnetism are very minute, so minute indeed that they can scarcely be perceived by the eye. If to one of these magnetometers, however, we attach a very small and light mirror, the plane of which is at right angles to the axis of the magnet, and cause a beam, proceeding from a source of light, to pass through a small aperture, thence to a fixed lens on to the mirror, which reflects the beam of light on to a screen so placed that the image of the aperture is in the focus of the lens, any small deviation of the magnetometer will cause the beam of light to deflect on the screen. The amount of the deflection will be dependent on the focal length of the lens, and the distance of the aperture and screen from the mirror. Suppose the screen to be opaque, and that a slit is cut in it in the direction that the deviation of the beam would take, and lying in the same plane as the deviation, and that a strip of sensitive paper moves behind that slit in a direction at right angles to its length, then at each instant the position of the beam of light will be registered on the paper. On developing the image we shall have a sinuous line corresponding to the deflections of the magnetometer at every time of day and night, the reading of the time being dependent on the rate at which the paper travels. This method is capable of application to any instrument in which the scale is dependent on the oscillations of a bar, needle, or surface. To the same class belongs the most recent application of Stein, when he shows the pulsation of, and also the effect of the human voice on, a stretched membrane.

For meteorological purposes we may also hope that photography will be more utilised than it has hitherto been. Mr. A. Mallock, at the meeting of the British Association at Plymouth, has shown a way in which it may be made subservient to ascertaining the heights of clouds.[1]

In military science it is only necessary to call to mind the service that the pigeon post performed during the siege of Paris. A large series of letters were printed on one sheet,

[1] *Photographic News*, Sept. 1877.

and then photographed to a very small scale on collodion pellicle. Such pellicles, measuring about 6 × 2 centimetres, were tied to pigeons, which when liberated carried the despatch to Paris, where they had been trained. On arrival the collodion pellicle was detached from the pigeon, placed in a lantern, and the letters transcribed and sent to the various addresses. Of so much use was this pigeon post that the German military authorities have established a regular service of pigeons in the chief fortresses of the Empire, which would be used in case of investment or siege by a hostile army.

During the investigation of the action of torpedoes the use of photography was also largely brought into requisition by the writer in order to ascertain the work that was expended by different charges of gun-cotton. The method adopted was roughly this:—A mine having been laid down at a known depth and position in water, a scale was placed over it, and photographed from the position the camera was to occupy. On the explosion of the gun-cotton or powder an instantaneous exposure was given to a specially sensitive plate, and the height, breadth, and general form of the resulting column of water was obtained from the photograph after comparing it with the photographic scale.

At Shoeburyness, again, a regular staff of photographers is kept in order to photograph all the experimental work carried on by the artillery against iron shields, &c., and the series of such pictures has been able to convey more to the minds of committees than the most elaborate drawings could do.

We cannot conclude these applications of photography without recalling the fact that it has proved exceedingly useful in the repression of crime. The portrait of every convict is taken by an authorised photographer in each convict establishment, and when necessity arises prints from such negatives are produced by the hundred and distributed, in order that the various police authorities may be enabled to identify a criminal who may have happened previously to be placed under their surveillance.

APPENDIX.

TABLE I.

Proportions of Absolute Alcohol by Weight in 100 *parts of Spirit of different Specific Gravities at* 60° F.

(Fownes, 'Phil. Trans.' 1847.)

Alcohol per cent.	Specific gravity	Alcohol per cent.	Specific gravity	Alcohol per cent.	Specific gravity	Alcohol per cent.	Specific gravity
0	1·0000	25	·9652	51	·9160	76	·8581
0·5	·9991	26	·9638	52	·9135	77	·8557
1	·9981	27	·9623	53	·9113	78	·8533
2	·9965	28	·9609	54	·9090	79	·8508
3	·9947	29	·9593	55	·9069	80	·8483
4	·9930	30	·9578	56	·9047	81	·8459
5	·9914	31	·9560	57	·9025	82	·8434
6	·9898	32	·9544	58	·9001	83	·8408
7	·9884	33	·9528	59	·8979	84	·8382
8	·9869	34	·9511	60	·8956	85	·8357
9	·9855	35	·9490	61	·8932	86	·8331
10	·9841	36	·9470	62	·8908	87	·8305
11	·9828	37	·9452	63	·8886	88	·8279
12	·9815	38	·9434	64	·8863	89	·8254
13	·9802	39	·9416	65	·8840	90	·8228
14	·9789	40	·9396	66	·8816	91	·8199
15	·9778	41	·9376	67	·8793	92	·8172
16	·9766	42	·9356	68	·8769	93	·8145
17	·9753	43	·9335	69	·8745	94	·8118
18	·9741	44	·9314	70	·8721	95	·8089
19	·9728	45	·9292	71	·8696	96	·8061
20	·9716	46	·9270	72	·8672	97	·8031
21	·9704	47	·9249	73	·8649	98	·8001
22	·9691	48	·9228	74	·8625	99	·7969
23	·9678	49	·9206	75	·8603	100	·7938
24	·9665	50	·9184				

Table II.

Showing the percentage amount of Nitric Acid (HNO_3) contained in Aqueous Solutions of various Specific Gravities.

(Kolb. Ann. Ch. Phys. (4) 136.)

HNO. per cent.	Specific Gravity		Contraction	HNO per cent.	Specific Gravity		Contraction
	At 0°	At 15°			At 0°	At 15°	
100·00	1·559	1·530	0·0000	64·00	1·415	1·395	0·0830
99·84*	1·559*	1·530*	0·0004	63·59	1·413	1·393	0·0833
99·72*	1·558*	1·530*	0·0010	62·00	1·404	1·386	0·0846
99·52*	1·557*	1·529*	0·0014	61·21*	1·400*	1·381*	0·0850
97·89*	1·551*	1·523*	0·0065	60·00	1·393	1·374	0·0854
97·00	1·548	1·520	0·0090	59·59*	1·391*	1·372	0·0855
96·00	1·544	1·516	0·0120	58·88	1·387	1·368	0·0861
95·27*	1·542*	1·514*	0·0142	58·00	1·382	1·363	0·0864
94·00	1·537	1·509	0·0182	57·00	1·376	1·358	0·0868
93·01*	1·533*	1·506*	0·0208	56·10*	1·371*	1·353*	0·0870
92·00	1·529	1·503	0·0242	55·00	1·365	1·346	0·0874
91·00	1·526	1·499	0·0272	54·00	1·359	1·341	0·0875
90·00	1·522	1·495	0·0301	53·81	1·358	1·339	0·0875
89·56*	1·521*	1·494*	0·0315	53·00	1·353	1·335	0·0875
88·00	1·514	1·488	0·0354	52·33*	1·349*	1·331*	0·0875
87·45*	1·513*	1·486*	0·0369	50·99*	1·341*	1·323*	0·0872
86·17*	1·507*	1·482	0·0404	49·97	1·334	1·317	0·0867
85·00	1·503	1·478	0·0433	49·00	1·328	1·312	0·0862
84·00	1·499	1·474	0·0459	48·00	1·321	1·304	0·0856
83·00	1·495	1·470	0·0485	47·18*	1·315*	1·298*	0·0850
82·00	1·492	1·467	0·0508	46·64	1·312	1·295	0·0848
80·96*	1·488*	1·463*	0·0531	45·00	1·300	1·284	0·0835
80·00	1·484	1·460	0·0556	43·53*	1·291*	1·274*	0·0820
79·00	1·481	1·456	0·0580	42·00	1·280	1·264	0·0808
77·66	1·476	1·451	0·0610	41·00	1·274	1·257	0·0796
76·00	1·469	1·445	0·0643	40·00	1·267	1·251	0·0786
75·00	1·465	1·442	0·0666	39·00	1·260	1·244	0·0755
74·01*	1·462*	1·438*	0·0688	37·95*	1·253*	1·237*	0·0762
73·00	1·457	1·435	0·0708	36·00	1·240	1·225	0·0740
72·39*	1·455*	1·432*	0·0722	35·00	1·234	1·218	0·0729
71·24*	1·450*	1·429*	0·0740	33·86*	1·226*	1·211*	0·0718
69·96	1·444	1·423	0·0760	32·00	1·214	1·198	0·0692
69·20*	1·441	1·419*	0·0771	31·00	1·207	1·192	0·0678
68·00	1·435	1·414	0·0784	30·00	1·200	1·185	0·0664
67·00	1·430	1·410	0·0796	29·00	1·194	1·179	0·0650
66·00	1·425	1·405	0·0806	28·00*	1·187*	1·172*	0·0635
65·07*	1·420*	1·400*	0·0818	27·00	1·180	1·166	0·0616

TABLE II.—*continued.*

HNO per cent.	Specific Gravity At 0°	Specific Gravity At 15°	Contraction	HNO per cent.	Specific Gravity At 0°	Specific Gravity At 15°	Contraction
25·71*	1·171*	1·157*	0·0593	11·41*	1·075	1·067*	0·0296
23·00	1·153	1·138	0·0520	7·22*	1·050	1·045*	0·0206
20·00	1·132	1·120	0·0483	4·00	1·026	1·022	0·0112
17·47*	1·115*	1·105*	0·0422	2·00	1·013	1·010	0·0055
15·00	1·099	1·089	0·0336	0·00	1·000	0·999	0·0000
13·00	1·085	1·077	0·0316				

*** The numbers marked * are the results of direct observations, the others are obtained by interpolation.

TABLE III.

Showing the Percentage of Sulphuric Acid (H_2SO_4) in Aqueous Solutions of various Specific Gravities.

(Bineau; Otto. Temp. 15°.)

Specific Gravity	Per cent.	Specific Gravity	Per cent.	Specific Gravity	Per cent.	Specific Gravity	Per cent.
1·8426	100	1·675	75	1·398	50	1·182	25
1·842	99	1·663	74	1·3886	49	1·174	24
1·8406	98	1·651	73	1·379	48	1·167	23
1·840	97	1·639	72	1·370	47	1·159	22
1·8384	96	1·627	71	1·361	46	1·1516	21
1·8376	95	1·615	70	1·351	45	1·144	20
1·8356	94	1·604	69	1·342	44	1·136	19
1·834	93	1·592	68	1·333	43	1·129	18
1·831	92	1·580	67	1·324	42	1·121	17
1·827	91	1·568	66	1·315	41	1·1136	16
1·822	90	1·557	65	1·306	40	1·106	15
1·816	89	1·545	64	1·2976	39	1·098	14
1·809	88	1·534	63	1·289	38	1·091	13
1·802	87	1·523	62	1·281	37	1·083	12
1·794	86	1·512	61	1·272	36	1·0756	11
1·786	85	1·501	60	1·264	35	1·068	10
1·777	84	1·490	59	1·256	34	1·061	9
1·767	83	1·480	58	1·2476	33	1·0536	8
1·756	82	1·469	57	1·239	32	1·0464	7
1·745	81	1·4586	56	1·231	31	1·039	6
1·734	80	1·448	55	1·223	30	1·032	5
1·722	79	1·438	54	1·215	29	1·0256	4
1·710	78	1·428	53	1·2066	28	1·019	3
1·698	77	1·418	52	1·198	27	1·013	2
1·686	76	1·408	51	1·190	26	1·0064	1

LIST OF ELEMENTS.

Names.	Symbols.	Combining Weights.
Aluminium	Al	27·4
Antimony	Sb	122
Arsenic	As	75
Barium	Ba	137
Bismuth	Bi	210
Boron	B	11
Bromine	Br	80
Cadmium	Cd	112
Caesium	Cs	133
Calcium	Ca	40
Carbon	C	12
Cerium	Ce	92
Chlorine	Cl	35·5
Chromium	Cr	52·2
Cobalt	Co	58·7
Copper	Cu	63·5
Didymium	D	95
Erbium	E	112·6
Fluorine	F	19
Glucinium	Gl	9·3
Gold	Au	197
Hydrogen	H	1
Indium	In	37·8
Iodine	I	127
Iridium	Ir	198
Iron	Fe	56
Lanthanum	La	92
Lead	Pb	207
Lithium	Li	7
Magnesium	Mg	24
Manganese	Mn	55
Mercury	Hg	200
Molybdenum	Mo	96
Nickel	Ni	58·7
Niobium	Nb	94
Nitrogen	N	14
Osmium	Os	199·2
Oxygen	O	16
Palladium	Pd	106·6
Phosphorus	P	31
Platinum	Pt	197·5
Potassium	K	39·1
Rhodium	Rh	104·4
Rubidium	Rb	85·4
Ruthenium	Ru	104·4
Selenium	Se	79·5
Silver	Ag	108
Silicon	Si	28
Sodium	Na	23
Strontium	Sr	87·5

LIST OF ELEMENTS—*continued.*

Names.	Symbols.	Combining Weights.
Sulphur	S	32
Tantalum	Ta	182
Tellurium	Te	128
Thallium	Tl	204
Thorium	Th	115·7
Tin	Sn	118
Titanium	Ti	50
Tungsten	W	184
Uranium	U	120
Vanadium	V	51·3
Yttrium	Y	61·6
Zinc	Zn	65·2
Zirconium	Zr	89·6

COMPARISON OF THE METRICAL WITH THE COMMON MEASURES.

FROM DR. WARREN DE LA RUE'S TABLES.

MEASURES OF LENGTH.

	In English Inches.	In English Feet = 12 Inches.
Millimetre	0·03937	0·0032809
Centimetre	0·39371	0·0328090
Decimetre	3·93708	0·3280899
Metre	39·37079	3·2808992
Decametre	393·70790	32·8089920
Hectometre	3937·07900	328·0899200
Kilometre	39370·79000	3280·8992000
Myriometre	393707·90000	32808·9920000

1 Inch = 2·539954 Centimetres. 1 Yard = 0·91438348 Metre.
1 Foot = 3·0479449 Decimetres. 1 Mile = 1·6093149 Kilometre.

MEASURES OF SURFACE.

	In English Square Feet	In English Sq. Yards = 9 Square Feet
Centiare, or sq. metre	10·7642993	1·1960333
Are, or 100 sq. metres	1076·4299342	119·6033260
Hectare, or 10,000 sq. metres	107642·9934183	11960·3326020

1 Square Inch = 6·4513669 Square Centimetres.
1 Square Foot = 9·2899683 Square Decimetres.
1 Square Yard = 0·83609715 Square Metre, or Centiare.
1 Acre = 0·404671021 Hectare.

Measures of Capacity.		
	In Cubic Inches	In Gallons = 8 Pints = 277·27384 Cubic Inches
Millilitre, or cubic centimetre	0·061027	0·00022010
Centilitre, or 10 cubic cents.	0·610271	0·00220097
Decilitre, or 100 cubic cents.	6·102705	0·02200967
Litre, or cubic decimetre .	61·027052	0·22009668
Decalitre, or centistere .	610·270515	2·20096677
Hectolitre, or decistere .	6102·705152	22·00966767
Kilolitre, or stere, or cubic metre	61027·051519	220·09667675
Myriolitre, or decastere .	610270·515194	2200·96676750

1 Cubic Inch = 16·3861759 Cubic Centimetres.
1 Cubic Foot = 28·3153119 Cubic Decimetres.
1 Gallon = 4·543457969 Litres.

Measures of Weight.		
	In English Grains	In Troy Ounces = 480 Grains
Milligramme . . .	0·015432	0·000032
Centigramme . . .	0·154323	0·000322
Decigramme . . .	1·543235	0·003215
Gramme	15·432349	0·032151
Decagramme . . .	154·323488	0·321507
Hectogramme . . .	1543·234880	3·215073
Kilogramme . . .	15432·348800	32·150727
Myriogramme . . .	154323·488000	321·507267

1 Grain = 0·064798950 Gramme.
1 Troy oz. = 31·103496 Grammes.
1 lb. Avd. = 0·45359265 Kilogramme.
1 Cwt. = 50·80237689 Kilogrammes.

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